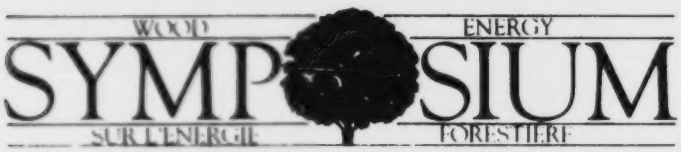
Final Report

A project under the Canada
New Brunswick Conservation
and Renewable Energy
Demonstration Program


WOOD
ENERGY
SYMPOSIUM
SUR L'ENERGIE
FORESTIERE

The Wood Energy Symposium was held February 26 - 28, 1984, in Fredericton. It was organized by the New Brunswick Energy Secretariat under the Canada/New Brunswick Conservation and Renewable Energy Demonstration Agreement (CREDA).

New Brunswick is a leader in the development of wood residues for energy and the Symposium was the first major conference in Canada to focus exclusively on that subject. All speakers have first-hand experience in this burgeoning industry.

The over one hundred participants -- who judged the Symposium a great success -- came from a broad variety of backgrounds, including forestry, engineering and government. In the two and a half day symposium they were presented with state-of-the-art information on all aspects of wood residue energy. They heard talks based on the enclosed papers, they attended an exhibit/poster session and tours of nearby installations, and took full advantage of opportunities for discussion.

A number of the Symposium papers are based on projects initiated under New Brunswick's comprehensive Wood Energy Program. Others are New Brunswick contributions from outside the Program, and still others provide valuable input from Prince Edward Island, Maine and Ontario.

It is to all those at the Symposium, speakers and participants, from inside New Brunswick and beyond, that these Proceedings are dedicated. The attendees, ultimately, deserve credit for the event's success.

TABLE OF CONTENTS

1. Supply
   - 1.1 Biomass inventory, G. van Raalte, Canadian Forestry Services . . . . . P. 1
   - 1.2 Manufacturing residue supply, J.L. LaPlante, Dept. of Natural Resources 10
   - 1.3 Harvesting residue supply, D. E.S. Fellows, Forestry Consultant. 14

2. Harvesting
   - 2.1 International residue harvesting development, Dr. C.R. Silversides, Forestry Consultant 26
   - 2.2 Residue harvesting on small freeholds, Dr. M. Schneider, University of New Brunswick 31
   - 2.3 Industrial residue harvesting on a sub-marginal tract, J. Ellingsen, Boise Cascade Canada Ltd. 39
   - 2.4 Industrial residue harvesting in a normal logging operation, P. McKinley, Fraser Inc. 44

3. Distribution
   - 3.1 Small scale transportation, drying & storage, Prof. C.A. Short, University of New Brunswick 49
   - 3.2 Large scale custom industrial delivery, W. Torunski, J.D. Irving Ltd. 51
   - 3.3 Medium scale distribution, J. Hornby, J.D. Hornby Ltd. 54

4. Combustion of Particulate Fuel
   - 4.1 Current developments in Maine, Dr. N. Smith, University of Maine, Orono 60
   - 4.2 Combustion installations in New Brunswick, D. Gorman, ADI Ltd. 65
   - 4.3 Residential unit certification and insurance, L. Morrison, Professional Loss Control Ltd. 76

5. Building Wood Energy Systems
   - 5.1 Wood energy in Maine, N. Holmes, Maine State Office of Energy Resources 80
   - 5.2 A regional wood energy industry, G. McKenna, Neill & Gunter Ltd. 87

6. The Organizing Committee 97
7. Staff 97

8. Speakers. 98

9. Delegates 100

1. SUPPLY

1.1 TOWARD A BIOMASS INVENTORY FOR NEW BRUNSWICK AND CANADA

G. van Raalte, Canadian Forestry Services

Introduction

Canadians are among the world's highest per capita energy consumers. At present, fossil fuels provide about 70% of our energy supplies with hydro-electricity, nuclear, and wood-based fuels the other 30%. Of the fossil fuel energy, approximately 60% is derived from crude oil. Canadian oil production has continued to decline by about 8% annually since peak production in the mid-1970s. Current oil imports amount to 25% of oil usage. Yet we live in a country with abundant renewable resources.

Canada's 4.4 million km^2 of forest land represent a major renewable energy source, but presently supplies only about 4% of our primary energy requirements. An estimated 10% of our requirements could be obtained from the forest by the year 2000. To realize this potential, the Canadian Government established, as part of its renewable energy thrust, the ENergy from the FORest (ENFOR) program (Dobbs 1981).

The ENFOR program was originally divided into two components: Production and Conversion. The Production program had four major broad objectives when established in 1978. These were

1) Biomass Resource Assessment,

2) Environment Impacts,

3) Silviculture of Fast Growing Species, and

4) Mechanization-Harvesting of Biomass

The major thrust has been to achieve the first of these objectives. In practical terms, data on the availability of the forest resource for conversion to energy and (or) chemicals were severely lacking. Traditionally, our inventories and production methods were developed in terms of the merchantable timber that is utilized by the established forest products industry. The measurement, harvesting and transport of the total biomass available in the forest, is introducing a new dimension into our forestry operations.

A Biomass Inventory

Central to a biomass inventory is the development of biomass estimation equations and their application to the existing forest inventory data of the province (Lindsay et al. 1983).

There are two ways to do this;

1. Factor Approach

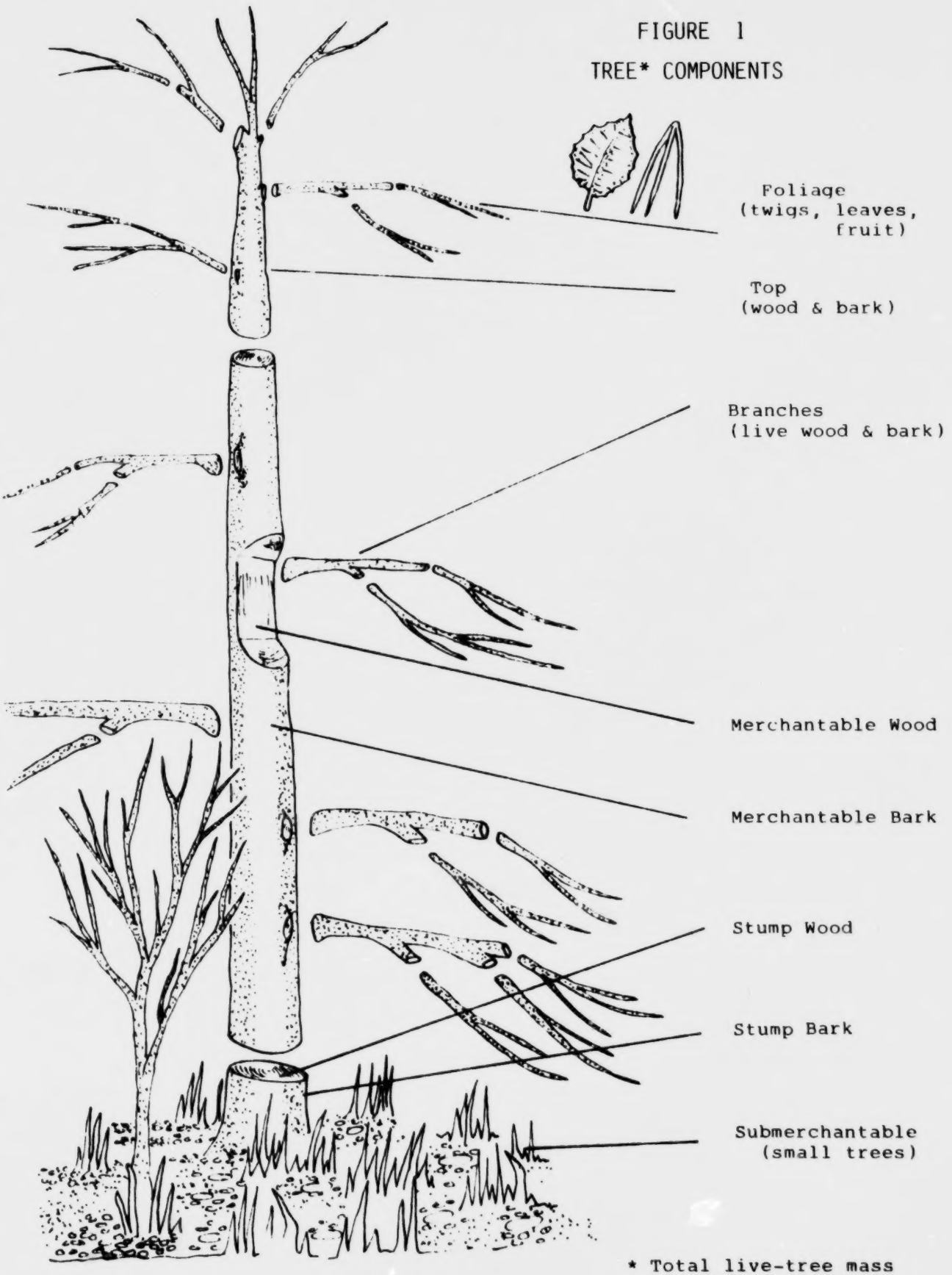
The factor approach is the simplist way to obtain a biomass inventory. The existing volume summaries are used and to these, wood density figures are applied. That takes care of the merchantable stem portion. Factors or equations are then developed that relate the biomass of the various tree components to the biomass of the main stem. This approach is fast, relatively cheap but not accurate.

2. Equation Approach

The other method, the equation approach is much more detailed and accurate because it directly applies individual biomass equations by components and species, to existing inventory plot data.

FIGURE 1

TREE* COMPONENTS



* Total live-tree mass above ground

To implement this approach, information has been collected over the past five years for about 12,000 trees of 40 major species across Canada. In the Maritimes, we have sampled about 2,300 trees comprising 17 species (Ker 1980a,b, 1984). Single tree mass equations for the following tree components (Fig. 1) have been developed that related ovendry biomass to the basic tree measurements of diameter or diameter and height.

1. Merchantable wood
2. Bark on merchantable wood
3. Stump wood
4. Stump bark
5. Unmerchantable top (wood & bark)
6. Branches (wood & bark)
7. Foliage

The field work necessary to obtain this data involves felling representative trees of each species, measuring height and diameter, weighing the total tree by components, and obtaining samples of all the components. The main criteria for sample tree selection are that the trees cover the full diameter range for each species, including the full range of height within each diameter class; and they are adequately distributed over the species' geographic range. Green samples of all compoenents are oven-dried in the laboratory to obtain dry mass values. Ratios of oven-dry mass to green mass are then derived and applied to the green mass data obtained in the field. For the Maritimes, the equation models developed are

$$W = a\, D^{b}$$

$$W = a\, D^{b} H^{c}$$

where: W = ovendry (or green) mass of a tree component (kg)

D = diameter at breast height outside bark (cm)

H = total tree height

a,b,c = regression coefficients

These equations (Ker 1984) provide for the calculation of stump wood and stump bark biomass as well as a set of coefficients to use in calculating the breakdown of the above stump biomass into merchantable and unmerchantable top portions.

Biomass Inventory - New Brunswick

In May 1983, the New Brunswick Department of Natural Resources entered into a contractual agreement with the Canadian Forestry Service (CFS) to convert the 1981 volumetric inventory of the Province to a biomass inventory, according to standards set by the Canadian Forestry Resource Data System (CFRDS) such that the New Brunswick Forest Biomass Inventory can be included in the National Forest Biomass Inventory. That work has now been completed and is documented by Fowler (1983, 1984). Figure 2 shows the condensed flowchart of the biomass compilation program used. New standard tables derived from plot tally data had to be developed for each resource region in the Province, and biomass per square kilometre calculated and summarized for each of the 686 map sheets, by the various strata in the CFRDS. This was a tremendously large undertaking; instead of one volume equation now seven biomass equations for each species or species group had to be handled. Biomass information from previously uninventoried land such as old fields, swamps, and nonproductive land, which had never been included in the provincial inventory also had to be sampled.

This undertaking has resulted in a biomass inventory which estimates that there is a total of 530.2 million ovendry metric tonnes of above-ground forest biomass in New Brunswick. This represents an average weight of 83.8 t/ha for the forest land, both productive and non-productive, in the Province.

The Canadian Forest Biomass Inventory

In 1980, the CFS initiated a program to obtain better nationwide forest resource data and formed the Forestry and Statistics Branch (FSSB).

The FSSB employs the Canadian Forest Resource Data System (CFRDS) to accumulate and report forest resource data on a national basis (Bonnor 1981). This computer-based system has been applied on a national basis to produce (in cooperation with the province) "Canada's Forest Inventory 1981" (Bonnor 1982). The national forest biomass inventory will be patterned after this inventory and developed in the same way using data generated by the provinces and territories.

CFRDS has two components: data handling and mapping. Prior to input into the data handling component, forest statistics are summarized by cells, 40,000 of them - usually 100 km map unit or townships used by the provincial and territorial agencies supplying the data - and converted to a national classification system. Data are listed in a file by cell reference number. A data management system has been developed to produce

- a set of standard tables;
- specially requested tabular summaries; and
- computer-compatible data listings for map production (Bonnor 1980).

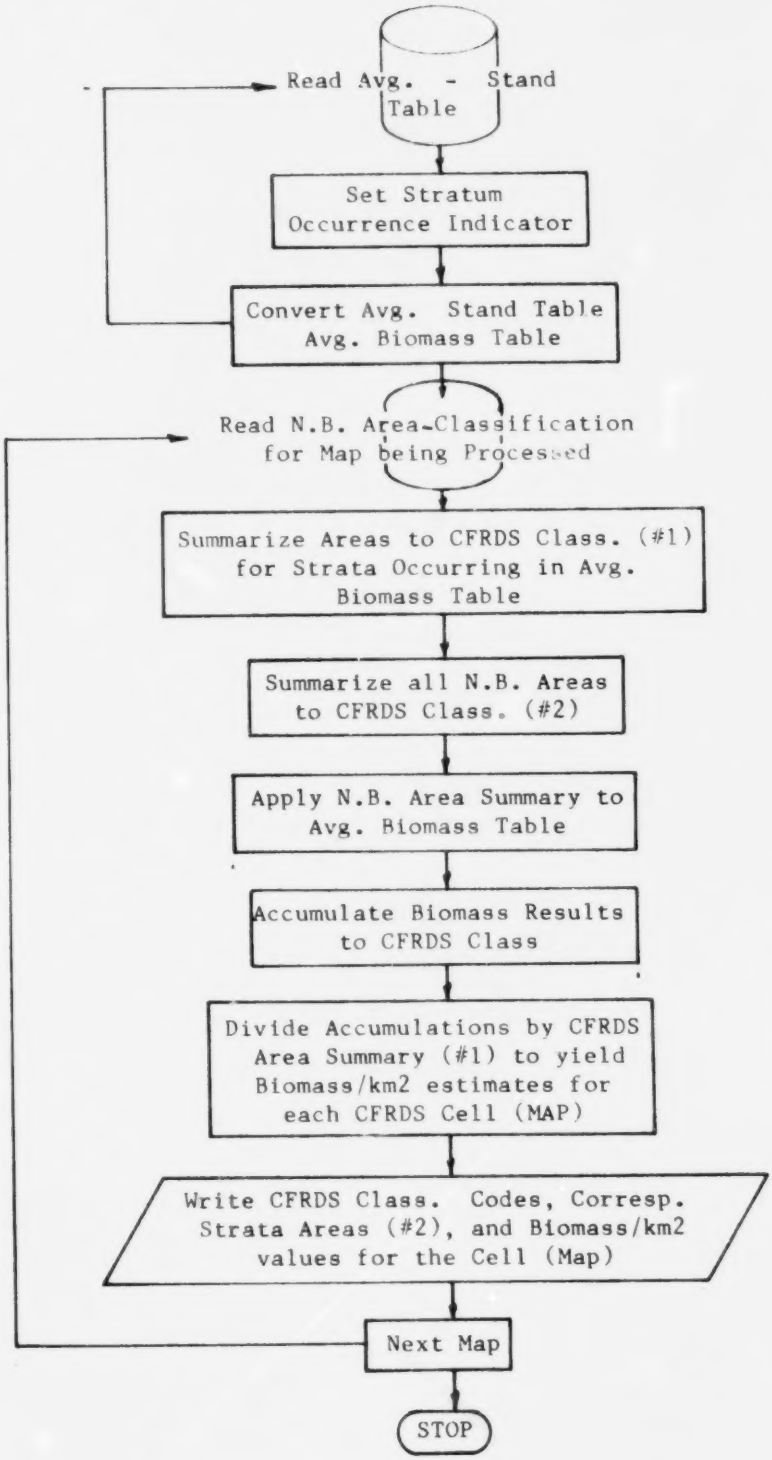

Read Avg. - Stand Table
Set Stratum Occurrence Indicator
Convert Avg. Stand Table Avg. Biomass Table
Read N.B. Area-Classification for Map being Processed
Summarize Areas to CFRDS Class. (#1) for Strata Occurring in Avg. Biomass Table
Summarize all N.B. Areas to CFRDS Class. (#2)
Apply N.B. Area Summary to Avg. Biomass Table
Accumulate Biomass Results to CFRDS Class
Divide Accumulations by CFRDS Area Summary (#1) to yield Biomass/km2 estimates for each CFRDS Cell (MAP)
Write CFRDS Class. Codes, Corresp. Strata Areas (#2), and Biomass/km2 values for the Cell (Map)
Next Map
STOP

Figure 2. Condensed flowchart of the biomass compilation program.

Mapping input data, consisting of maps of cell boundaries with reference numbers and major geographic features, are digitized and stored in the computer. To produce maps of forest resource attributes (e.g., biomass estimates), percentages or absolute values are extracted from the data base, merged with the digitized map information and plotted. The mapping component of the CFRDS can produce choropleth maps for desired attributes in two series: for Canada and for individual provinces or territories. The results are readily used for policy and planning purposes on the national and provincial levels.

Conclusion

One of the key benefits of this program has been the incorporation of biomass equations and other forest biomass estimators into the provincial inventory system. Now, the province is able to generate both volume and biomass by component estimates for virtually any piece of forest land for which inventory statistics are available.

References and Additional Reading

Bonner, G.M. 1980. Accumulation of summarized forest inventory data for Canada - a status report. Environment Canada, Canadian Forestry Service, Petawawa National Forestry Institute. 30 p.

Bonner, G.M. 1981. The Canadian Forest Resource Data System. Paper for In-Place Resource Inventories Workshop, University of Maine, Orono Aug. 9-14, 1981. 8 p.

Bonner, G.M. 1982. Canada's Forest Inventory - 1981. Environment Canada, Canadian Forestry Service, Forestry Statistical and System Branch. 79 p.

Dobbs, R.C. 1981. ENFOR biomass production program. Canadian Forestry Service Headquarters, Hull, Quebec. Internal Report. 35 p.

Fowler, D. 1983. Trial Conversion of Conventional Inventory Data to Biomass Data in New Brunswick. ENFOR Project P-238, Maritime Forest Research Centre, Fredericton, N.B.

Fowler, D. 1984. Compilation of the Forest Biomass Inventory of New Brunswick. ENFOR Project P-268. (Unpublished)

1.2 MANUFACTURING RESIDUE SUPPLY

J.L. Laplante, Dept. of Natural Resources

The following presentation provides a Regional view of manufacturing residue supply, in a provincial context.

Parameters:

1. Reference is made to Forest Region 5 -- a DNR subdivision for the Northwestern part of the province.
2. There are 22 mills surveyed of various sizes in Forest Region 5.
3. Three mills outside of the boundaries are included because of proximity to the Region and their effect on the local economy.

Definitions:

Sawmilling residue is defined as chips, sawdust, planer shavings and bark. I have not concentrated on the production of wood chips since they are used mostly in the production of pulp and not as an energy bi-product.

With the demand for energy that we have today, sawmilling residues should be considered as bi-products that can be sold. Disposal by landfill or burning should become thing of the past.

The following tables show the wood residue situation in Forest Region 5 and in the province as a whole. For reasons of confidentiality, the 22 mills in the Region are grouped into three categories:

- Large (mills utilizing 40,000 cunits or more).
- Medium (mills utilizing 20,000 - 40,000 cunits).
- Small (mills utilizing up to 20,000 cunits).

Table 1

WOOD RESIDUE SURVEY 1984
Forest Region 5
Sawmilling

Company (Grouping)	Roundwood Manufactured (Cu.)	B.D.T. Sawdust Generated	B.D.T. Shavings Generated	B.D.T. Bark Generated	B.D.T. Slabs Generated
LARGE Defined as utilizing 40,000 cu. and more.	348,000	57,072	37,410	51,330	
MEDIUM Defined as utilizing 10,000 cu. up to 40,000 cu	64,000	13,376	3,655	10,715	3,125
SMALL Defined as utilizing up to 10,000 cu.	34,610	6,984		2,850	15,560
TOTALS	446,610	77,432	41,065	64,895	18,685

Table 2

1984 SUMMARY ESTIMATES
Industrial Wood Residue Generation & Utilization
(OVEN DRY TONS)

REGION	Residues Generated							CURRENT UTILIZATION	SURPLUS (Deficit)
	PULP - PAPER PLYWOOD - PANEL MILLS		SAWMILLS				TOTAL		
	BARK	CLARIFIER SLUDGE	BARK	SAWDUST	SHAVINGS	SLABS			
I	54,000	14,000	20,500	34,400	13,500	7,700	144,100	125,000	19,000
II	80,500	15,000	19,000	32,700	13,400	9,500	170,100	125,200	44,900
III	83,000	10,000	34,100	40,800	17,000	10,500	195,400	34,100	160,900
IV	72,000	3,000	47,900	49,200	33,700	12,500	218,300	193,400	24,900
V	24,000	19,000	39,600	52,300	22,600	20,800	178,300	26,900	151,400
PROVINCIAL TOTALS									
	313,500	61,000	161,100	199,400	100,200	61,000	906,200	504,600	401,600

Notes: Residue generation estimates above are based on in-Province industrial processing of approximately 3.1 million cunits of roundwood.

Roundwood volumes processed in-Province vary from year to year, eg:
1979 - 3.20 million cunits
1980 - 3.37 million cunits
1981 - 3.18 million cunits
1982 - 2.39 million cunits

Of the total industrial wood residues utilized, approximately 70,000 O.D. Tons is manufactured into wood products. The balance is used as fuel for energy generation.

In Table 2, the present utilization of residues is as follows:

	B.D.T.
Fraser Edmundston	24,000
Madawaska Regional Correctional Center	300
College St-Louis Maillet	2,000
Edmundston Regional Hospital (estimated)	2,200
	28,500

As an example of the cost savings involved in utilizing wood wastes for heat generation, consider the relative heating costs at the Madawaska Correctional Center for 1982, when it heated with oil, and for 1983, when it heated with wood residue:

1982	35,683 gals. oil		$58,163,00
1983	550 green tonnes		$19,173,00
		Saving	$38,990,00

In closing I would comment that with future demands on energy fuels you will see less and less disposal of wood residues with burners or as landfill, and a greater use of for heat generation.

1.3 HARVESTING RESIDUE SUPPLY: PRESENT AND FUTURE IMPLICATIONS

Dr. E.S. Fellows, Forestry and Forest Products Consultant

Surely wood, or some form of cellulose, must have been the earliest fuel known to man: and he has used it almost worldwide for that purpose ever since he discovered fire. But wood is also one of the most versatile materials known to man and it has served him well in a multitude of uses throughout his history.

Until now, there has been enough wood to supply all demands with only isolated but increasing areas of scarcity. However, that situation is rapidly coming to an end. For at least the past 20 years a global shortage of wood within decades has been reliably predicted. The end of this century will probably see the world reach a precarious balance between supply and demand. Canada, including New Brunswick, will feel the pinch by then even though the supply picture may be holding more "promise" by that time.

Although we in New Brunswick even now have our "backs to the wall" in finding supplies of softwood adequate to maintain our forest industries, we still leave a great deal of woody biomass on the forest floor following harvesting operations. We are also abandoning significant volumes of standing timber of species or qualities not presently in demand where they happen to be growing.

A study in the Miramichi basin (1) reveals that there were about 43 metric tonnes (oven-dry basis) (odt) of logging slash plus another 4 odt of residual standing timber on an average hectare of recently logged area.

Calculated in another way, these numbers translate into a quantity close to 300 odt of woody biomass abandoned for each one thousand cubic metres of industrial wood harvested.

A theoretical calculation using average conditions in Nova Scotia suggests a comparable figure of roughly 250 odt per thousand cubic metres of industrial harvest. Prince Edward Island has about the same mixture of species as the other Maritime Provinces, so probably a similar proportion of logging slash and uncut timber is left following harvesting.

Newfoundland's forests contain a much smaller proportion of hardwoods than the other Atlantic Provinces, so that there the weight of logging slash and residual trees is probably slightly less per unit of industrial wood removed, although the volume is probably about the same.

In round numbers, therefore, we may assume that the three Maritime Provinces produce an average of about 275 odt for each thousand cubic metres of industrial wood harvested, while in Newfoundland the corresponding weight might be closer to 265 odt.

Table 1 shows the average harvest of industrial wood for the five-year period 1977 through 1981 in thousands of cubic metres for each of the four Atlantic Provinces. These quantities are multiplied by the estimated weights of residues for each thousand cubic metres of harvest. The totals are then converted to the equivalent volumes of No. 6 (Bunker "C") fuel oil after taking into account the conditions for the combustion of each fuel. That is to say, an overall combustion efficiency of 65 per cent for wood and 80 per cent for No. 6 oil and assuming that the wood is actually burned at a moisture content of 80 per cent (oven-dry basis).

Table 1: Estimated Quantities of Wood-Harvesting Residues and Standing Residual Trees and Equivalent Quantities of No. 6 (Bunker "C") Fuel Oil.

Atlantic Region -- Averages for the Years 1977 through 1981.

PROVINCE	Average Annual Harvest of Industrial Wood (a)	Estimated Weight of Residual Biomass per 1000m3 of Harvest	Estimated Total Weight of Harvesting Residues	Equivalent Quantities of No. 6 Fuel Oil (b)
	'000m3	Tonnes (oven-dry base)		Barrels
Newfoundland	2 227	265	590 000	1 428 000
Nova Scotia	3 920	275	1 078 000	2 609 000
Prince Edward Island	151	275	42 000	100 000
New Brunswick	7 999	275	2 200 000	5 323 000
All Atlantic Provinces	14 297	273.4	3 910 000	9 460 000

(a) Source: Statistics Canada annual reports No. 25-202 for the years involved.

(b) The equivalent quantities of No. 2 fuel oil would be about 9 per cent greater.

Of course, the figures in Table 1 are only educated estimates of the total quantities of wood biomass abandoned in industrial logging operations in the Region. Conditions can very quite widely from one locality to another. Therefore, the foregoing estimates could well be in error in either direction by 20 per cent for any one Province and perhaps by at least 10 per cent for the Region as a whole.

But all the foregoing figures are based on physical availability which is a very different thing from economic availability. Economic availability takes into account the relative costs of competing sources of energy and the capital costs of all the facilities needed to use each type of fuel. For industrial or institutional generation of energy, facilities for burning wood are the most expensive of any energy-conversion system in common use. As for the cost of fuel itself, the method of logging, the nature of the terrain, the size of the operation and the transportation distances to the point of use are the principal factors influencing the delivered costs of logging residues in the form of fuel.

Although special machinery is being evolved to pick up logging slash from the forest floor and convert it to chips, experience shows that the cheapest comminuted wood-fuel is still that made from the tops and branches of trees which are carried intact from their stumps to a central, roadside, processing yard. Even then the costs of transporting such fuel to the point of use may render it non-competitive.

Rough or boulder-strewn terrain obviously inhibits, or even prohibits, picking slash off the ground, but does not increase the cost of fuel chips "at roadside", provided that all the costs of whole-tree logging are charged against the industrial feedstock produced. Small operations cannot afford the use of equipment capable of achieving acceptable production costs on a large scale.

Large stands of low-grade timber of little or no present value for pulp or structural material can be economically harvested for industrial or institutional fuel if the users are located reasonably close to the point of production (seldom more than 100 kilometres but often much less) and if the needs and capabilities of the users are compatile with this form of fuel (1).

Overall, therefore, the economic availability of forest biomass is far less, than its physical availability. What the difference is on a regional basis can only be guessed, but it may be that only one-third to one-half of the available supply can be considered cheaper than alternative sources of energy. But even at the lower estimate, we are talking of a substitution of about three million barrels of oil per year worth roughly 105 million dollars in the Atlantic Region -- perhaps 60 million dollars of which would be in New Brunswick.

These figures could conceivably be much higher, but it seems unlikely that harvesting residues economically recoverable as fuel will exceed two-thirds of the physically available quantities within the foreseeable future in the absence of any sharp rise in the costs of other energy sources or a major break-through in equipment and/or system design. Furthermore, under certain circumstances it can be environmentally unwise to remove all wood biomass from an area (1).

So far we have been concerned with quantities of wood fibre left unused during timber harvesting operations in the Atlantic Region. Attention was earlier drawn to the fact that worldwide demands for wood for industry and for fuel are rapidly coming into balance with available supplies. The question that arises from these considerations is whether the use of wood fibre for fuel in the industrialized world will continue to be an economically viable option and, if so, for how long.

Not only is wood an acceptable fuel in its raw state, but it can also be converted into other forms of latent energy -- charcoal, producer gas, methanol and ethanol. However, in any of these forms it is less than an ideal source of energy, except under special and unusual circumstances.

Raw wood has a low calorific value per unit of mass as compared with fossil fuels (i.e., it is bulky), it has a high initial moisture content and its rate of combustion is relatively difficult to control. As charcoal it is invaluable for certain metallurgical uses, but as a general-purpose fuel it is even more bulky than raw wood, is far more expensive and dissipates energy in the process of its manufacture. Gaseous and liquid fuels can be produced at considerably less cost either from geological supplies or by manufacture using other raw materials.

Wood can also be used to produce a number of products edible by man and/or beasts -- sugar, alcohol, yeast and fodder to name only the more important ones. But, with some exceptions, the same foodstuffs can be produced at lower cost from other raw materials, although there are a few instances in which wood may be nearing a competitive position.

However, it is in the realm of commercial fibre and structural products that wood comes into its own as a strongly competitive materials in a wide range of uses. In discussing energy resources and energy conservation, it is very important to note that wood can be transformed into consumer goods and structural products with far less energy than most of the other materials with which it can compete. Thus, wood can fulfil two functions in any rationalization of energy supply and demand. It can either be used to <u>enlarge the supply</u> of energy (i.e., be used as fuel) or it can be used to <u>reduce the demand</u> for energy be being substituted for other materials which consume more energy in their manufacture. Of course, wood used for fuel cannot also be used as a raw material; but, paradoxically, if it is first used as a raw material, it still retains most of all of its original fuel value. Thus, if so desired, it can be burned after it has served its prime function.

Table 2 indicates how wood can be used to reduce energy consumption through substitution for other materials. It ranks a number of common materials -- mostly structural ones -- in order of the amount of energy consumed in their manufacture (2). The Table relates energy inputs to certain attributes of the materials, namely, their mass, their tensile strength and their moduli of rigidity. Softwood lumber heads the list and is arbitrarily

Table 2: Relative Energy Consumption and Strength of Selected Materials*

Material	Energy Input per unit of mass	Energy Input per Unit of Strength	
		Tensile Strength	Modulus of Rigidity
Sawn softwood	1.0	1.00	1.00
Tempered hardboard	3.0	2.11	1.04
Reinforced concrete	4.6	8.06	1.10
Steel (EN-1)	33.0	27.89	3.26
Steel (EN-24)	33.0	8.70	3.26
Cast iron	32.0	16.28	6.68
Copper-zinc alloys	33.0	19.17	7.40
Plastic			
Polypropylene	40.0	28.61	n.a.
PVC rigid	40.0	31.11	n.a.
Aluminum alloys	158.0	39.44	16.40
Titanium alloys	310.0	40.56	31.06
Magnesium alloys	330.0	57.17	22.34

* Adapted from "Consistent energy accounting in production of wood products and competing materials" by Antoni Tenwolde and Robert N. Stone (Paper presented at the Resource Recovery and Conservation Symposium, 1978, quoting "Forest Products: an assured future" by E. A. Raynham. Timber Trades Journal 296 (5186) 19-20.

assigned "unity" value in each column simply for convenience in making comparisons. All materials thus acquire relative values without being quantified in absolute terms. For example, the first column of figures shows that it takes 158 times as much energy to produce a unit of mass (e.g., one kilogram) of aluminum as it does to produce the same amount of softwood lumber. Comparing materials "pound-for-pound" is not relevant in all cases, so the second and third colums of figures use tensile strength and modulus of rigidity as the criteria upon which to rate energy consumption. It is noteworthy that all these comparisons show softwood lumber to be the most "energy-effective" of all the listed materials, with tempered hardboard (a wood-fibre panel material) occupying second position -- and in nearly all instances the margin of superiority is large.

From the data in Table 2 it follows that, if energy costs rise faster than other costs, wood will progressively improve its competitive position vis-a-vis other structural materials as the spread in costs widens. Although the Table does not include brick or concrete, the same comparison also applies to them; indeed, it even applies in the comparison between hardwood flooring versus carpet and padding (3). Hence, it is generally true not only that the use of wood instead of other structural materials is a form of energy conservation, but also that, the higher the costs of energy relative to other costs, the more economically attractive wood becomes in relation to other materials for which it can be substituted. Of course, if energy costs should go <u>down</u> relative to other costs (no longer an "unthinkable" proposition!) wood would lose some or all of its recently acquired competitiveness as a fuel.

Even before the traumatic escalation of energy prices starting in the mid-1970's, projections of world consumption of forest products showed steady increases through to at least the end of this century.

Although the current recession has put a dip in the upward trend, rising energy costs have done little to reduce these expectations. This is hardly surprising in view of the evidence deduced from Table 2 above.

Without going into details of the expected increase in the use of different categories of forest products, such as pulp, paper, packaging, lumber, and panelboards* of several kinds, the global use of wood for manufactured goods is forecost to climb from about 1,341 million cubic metres in 1974 to 2,508 million cubic metres by the year 2,000 -- an increase of 87 per cent in just one-quarter of this century (4). The use of wood for fuel in the developing countries of the world will also increase somewhat, but will be constrained in many areas by scarcity. The use of wood for fuel in the industrialized countries is expected either to increase slightly or even to decline through the coming years (4) and (5). However, worldwide use of wood for all purposes is projected to graw from 2,511 million cubic metres in 1974 to 3,800 million cubic metres by the year 2,000 -- an increase of 51 per cent with developing scarcities imposing some harsh constraints in certain areas (4).

To a New Brunswick audience statistics of this kind may seem to have only tenuous relevance, but a couple of reminders may serve to give them local impact. A 1957 New Brunswick study (6) brought out the fact that at least two and one-quarter million cubic metres of wood remained unused from the very conservatively estimated provincial annual allowable cut which assumed no investment in silviculture. Twenty-five years later we are acutely aware of the fact that our softwood needs cannot be sustained without major outlays on

* "Panelboards" is a generic term which includes such products as plywood, particleboard, flakeboard, chipboards, insulating board, hardboard (e.g., "Masonite") and composite wood-fibre panels.

silvicultural treatments and our present annual growth of hardwoods is not far from being fully committed. This not-unrelated trend in the industrial use of hardwoods developed about mid way through the same period; in the decade between the late 1960's and the late 1970's the use of hardwoods by New Brunswick forest industries increased by a factor of thirteen -- further increases are in immediate prospect. Few people seem to realize how fast the output of Canadian forest industries has increased in recent years, especially those in New Brunswick.

What has this to do with industries and institutions using harvesting residues for fuel? Simply this: because of looming shortages of traditional forms of industrial wood fibre, a great deal of research and experimentation has gone into finding ways to use parts of trees formerly rejected, that is, the bark, branches, tops and even leaves and stumps in some cases. Today these materials can be satisfactorily processed into various kinds of pulp and panelboards and they have a potential for use in producing useful chemicals. Although serious problems still have to be overcome, great progress in this direction has already been made. Many of the experiments have moved out of the laboratory into pilot plants and in some cases have entered regular commercial production, albeit on a limited scale. There can be little doubt that, as shortages develop in conventional supplies of wood fibre, forest industries will be in a position to use as manufacturing feedstock much (or even all) of what is now regarded as only a neglected source of energy. The logic of both the marketplace and conservation surely indicates that goods will win out over calories in the not-very-distant future, regardless of the direction in which energy costs move.

In New Brunswick this trend has only just begun and it will not be completed suddenly. Therefore, for the present, efforts to use harvesting residues for fuel should be encouraged because this not only is highly desirable economically but also has very useful side effects in forest management. Nevertheless, the handwriting is on the wall, and prudence dictates that widespread use of wood fibre for fuel should be regarded as transitory in the industrialized world. Such material will have higher economic and social values for the attainment of more lasting benefits.

One comparison may serve to illustrate this last point and leave the reader with a question to answer. A fuel-efficient bungalow of about 120 square metres of floor space located in central New Brunswick might be assumed to need an average of eight cords of softwood every year for heating. The equivalent of one year's fuel could provide enough lumber to frame an entire house of modern design of the same size as well as enough panelboard to close it in -- roof and all. Such a house should have a life-expectancy of at least 50 years. When the availability of resources no longer permits both uses, which one is likely to prevail?

References:

1. A.D.I. Limited, Woodlot Service (1978) Limited and Edward S. Fellows. "Economic availability of harvesting residues". New Brunswick Energy Secretariat, Fredericton, N.B. (In press.)
2. Fellows, E.S. "Potential for energy from New Brunswick forests; implications for the forest economy". Paper prepared for Sylvicon '80, Fredericton, N.B. February 19-20, 1980.

3. Tenwolde, Antoni, and Robert N. Stone. "Consistent energy accounting in production of wood products and competing materials". (In "Resource Recovery and Conservation, 3(1978) "pp. 249-259. Elsevier Scientific Publishing Company. Amsterdam. 1978.

4. Stone, Robert N. and Jerome F. Saeman. "World demand and supply of timber products to the year 2000". Forest Products Journal 27(10) (October, 1977). pp. 49-54.

5. Roberts, Ralph W. "Third world forestry imperaties and Canadian prospects for meeting future wood product requirements". (Citing FAO of United Nations data). Paper presented at the 1983 Annual General Meeting of the Canadian Institute of Forestry. Canadian International Development Agency, Ottawa. 1983.

6. Anon. "Report of the New Brunswick Forest Development Commission". Fredericton, N.B. 1957.

2. HARVESTING

2.1 INTERNATIONAL RESIDUE HARVEST DEVELOPMENTS,

Dr. C.R. Silversides, Forestry Consultant

The international energy agency of the organization for economic co-operation and development (OECD) was established after the OPEC crisis in 1973, to implement the international energy program which had been adopted by the participating countries on November 18, 1974. The function of the program was:

- to take measures to meet oil supply emergencies,
- to reduce dependence upon imported oil by undertaking long-term co-operative efforts on conservation of energy, on accelerated development of alternative sources of energy and on research, development and demonstration in the energy field.

Within the context of the agency's long-term co-operative program the participating countries agreed to carry out national programs on energy research, development and demonstration and to undertake co-operative activities including jointly financed programs and projects in energy research and development.

In April 1978 Canada signed an implementing agreement to participate in this program. Activities in the program have dealt with growth and production, harvesting and transport and conversion.

Our interest this morning is in harvesting and transport. The lead agent for this activity is Sweden and the individual in charge of the international co-operative effort is Prof. P.O. Nilsson, College of Forestry, Swedish University of Agricultural Sciences, Garpenberg.

Residue harvesting developments in the participating countries will be found to be in varying stages, dependent in large part upon the national priority regarding renewable energies. Some countries, like Sweden and Finland who have no fossil fuel resources have given biomass a high priority, others like Canada with an abundance of gas and coal and at present an indeterminant resource of oil has given biomass a much lower priority, staying in the game to hedge its bets.

From a recent report received from IEA, of the ten countries signatory to the forestry energy agreement, Canada has the largest consumption of energy per capita. It is fifth among the group in the percentage of energy at present supplied from biomass (three percent compared to Finland's nineteen percent for example), it is first in area of productive forest per capita and second in the amount of money spent on government R and D for bioenergy. We use a lot of energy compared to the others because of climate, great distances and large energy-demanding extractive industries.

In the utilization of forest residues, amongst the countries, there is a great similarity in the systems and equipment presently in use and visualized for the future. Of course, there are regional preferences and national situations and priorities which are not universal. For example the nordic countries are attacking the mechanization of coniferous thinning under intensive forest management. This is not a problem in Canada although it is of interest to the southern United States. Fibre shortages have led Sweden and Finland to look at the harvesting of stumps after the final harvest clear-cut operation. This was initially for the pulp industry but applies equally for energy - with the processed wood being fractionated, the high quality chips going for pulp and the remainder for energy.

Logging for conventional forest products and harvesting forest biomass may or may not use the same or similar equipment, depending upon the system used. Logging equipment is designed to permit the selection of individual stems of merchantable species size and quality and their handling and transport. Only the bole wood is utilized and may be in tree length, log or bolt length.

Harvesting biomass for energy feedstock is oriented to producing the greatest mass per unit area of forest at the lowest cost. In many instances such harvesting may be more akin to land clearing technology than to logging.

In the development of methods and equipment to harvest biomass we have a classic chicken and egg situation. Until there is a sufficient demand for forest biomass it will not be possible to have suitable equipment developed for its production, and the demand for forest biomass will lag until biomass can be produced at an acceptable cost. It is for this reason that much of the equipment developed to date is funded in whole or in part by one or other levels of government. This is true in all of the other countries in the co-operative agreement as it is in Canada.

In the ten signatory countries a total of approximately 150 projects in the areas of harvesting, preparation, transport and storage of wood fuels have been identified, under headings as follows:

Systems Analysis	19 Projects
Harvesting of Conventional Forests	55 Projects
Harvesting of Energy Plantations	17 Projects
Fuel Preparation	24 Projects
Storage and Drying	8 Projects
Measuring of Forest Fuels	5 Projects
Ecological Consequences	19 Projects
	147 Projects

Within the IEA Program there are some seven co-operative projects underway:

CPC-2 - Development of harvesting systems and equipment for short rotation forests.

CPC-3 - Development of methods and equipment for the preparation and comminution of forest biomass with respect to harvesting, transportation, drying and storage, for optimal conversion by various processes.

CPC-4 - Development of methods and equipment for the stand establishment of fast-growing tree species for energy plantations.

CPC-5 - Development of a consistent system for evaluating promising machines for harvesting small trees and logging residues which are currently in use, under development or in the planning stage.

CPC-6 - Development of methods and equipment to harvest and collect logging residuals and residues including stumps, and to transport them both off and on the road.

CPC-7 - Development of methods and small-scale equipment for felling and bunching small trees from thinnings on gentle terrain.

CPC-8 - Examination of existing machines and systems that can be used to harvest conventional forest products and wood for fuel in a "one pass" process and to make recommendations for co-operative development work.

The co-operative projects described above are in varying stages of completion. As is usual in such activities there are more on-the-shelf projects waiting for money and personnel to activate them.

This particular area of co-operation in 1984 will cost Canada 440,000 sek or approximately $70,400 Can. I think you will agree that this is a good investment.

2.2 RESIDUE HARVESTING ON SMALL TRACTS,

Dr. M. Schneider, University of New Brunswick

This presentation is based on the author's experience with a small scale chip harvesting processing and supply demonstration project undertaken with the assistance of the Canada/New Brunswick Conservation & Renewable Demonstration Agreement. The final report of this project is available from the N.B. Energy Secretariat.

The project was carried out in collaboration with Prof. C.A. Short, Prof. E.J. Rickards, and Mr. J.E. Kipping.

1 PROJECT SCALE

The fuelwood chip project demonstrated chip production and supply at the small scale where capital and manpower requirements are low.

2 EQUIPMENT HARVESTING DEMONSTRATIONS

The project carried out several demonstrations in which slash left over from commercial (log and pulpwood) clearcuts, thinnings and small-sized hardwoods were harvested and chipped. Several combinations of equipment were used. Further details are given in Table 1.

3 STANDS HARVESTED

Small blocks were harvested. These were intended to represent forest land suitable for small-scale chip harvesting. The chosen locations, their area and the types of forest they contained are given in Table 2.

4 HARVESTABLE BIOMASS ESTIMATES

Blocks were measured before harvesting and the amount of biomass expected to be available was computed. These results were compared to chip production. The calculated values overestimated chip production by a large margin (Table 3).

5 PRODUCTIVITY OF MEN AND MACHINES

Table 4 summarizes project chip production per unit of time for men and machines. These values serve as bases for cost estimates. Cords per hour are given for those familiar with such units, and for purposes of comparison.

6 ENERGY BALANCE

The chip combustion energy (higher heating value) was from 13 to 47 times greater than the energy required to harvest, chip and transport them. More energy was required to chip than to harvest, with that required for transport dependent upon distance. With the transportation system used in the project, distances beyond about 100 kilometres would require greater energy to truck the chips than they would yield when burned. More details are given in Table 5.

7 CHIP COSTS

Table 6 gives average project costs of producing fuelwood chips, where chips were the only product obtained for the expenditures.

Table 7 shows costs of one project block where there were three objectives to the harvest; thinning for better growth, thinning to improve the appearance of the stand and fuelwood chip production. With costs shared, chip costs are reduced.

Labour and equipment ownership costs are not usually considered when homeowners produce their own fuelwood. Table 8 shows costs for chip fuel production accounted similarly to homeowner-prepared fuelwood. Only machine operating costs (as experienced in the project) are considered. Such accounting makes fuel chips very cost attractive.

8 COSTS TO HEAT WITH CHIPS

Chip burning installations require fuel storage facilities and equipment to feed the chips into the furnace. Both add to the cost of heating with woodchips and should be considered when comparing the cost of chip fuel to alternative fuels.

Considering the site-specificity of installation costs and the situation-specificity of chip fuel costs, each individual businessman or building owner will need to estimate his expected costs and benefits before making decisions about wood chip heating. The data given in the final report of the wood chip project will help in making those estimates.

9 DESIGN INFORMATION

The final report of the wood chip project gives information which can assist with design of chip production, processing and transportation systems. Some of this information is summarized in Tables 9 and 10.

TABLE 1 EQUIPMENT USED TO HARVEST STANDS

Designation	Forwarding	Transport
Slash 1	Skidder	Farm Trailer
Slash 2	Farm Tractor and winch	Farm Trailer
Thin 1	Farm Tractor and winch	3-ton dump truck
Thin 2	Yankee Yarder	Ro-Ro*
Clear 1	Farm Tractor and Winch (same Tractor to Chip)	Ro-Ro
Clear 2	Skidder	Ro-Ro
Clear 3	Skidder	Ro-Ro
Clear 4	Farm Tractor and Winch (another tractor to chip)	Ro-Ro
Clear 5	Same as Clear 4	Ro-Ro

* ROLL ON - ROLL OF CONTAINER, 85 OR 113 CU M

TABLE 2 DESCRIPTIONS OF STANDS HARVESTED

DESIGNATION	LOCATION	AREA (HECT.)	AVERAGE STEM DIAM. (CM)	AVERAGE STEMS/HECT.	TONNES/ HECT.**
Slash 1	Private Woodlot	0.7	-	-	
Slash 2	Private Woodlot	0.4	-	-	
Thin 1	UNB Woodlot	0.8	5.6*	9435*	87.5
Thin 2	UNB Campus	1.8	13.9*	3839*	241.7
Clear 1	CFB Gagetown	0.2	9.2	5800	84.3
Clear 2	CFB Gagetown	0.2	7.0	4200	115.7
Clear 3	CFB Gagetown	0.2	7.2	7800	138.7
Clear 4	UNB Woodlot	0.2	7.2	5400	101.2
Clear 5	UNB Woodlot	0.2	6.9	3600	105.2

* AVERAGE FOR STAND, BUT NOT MATERIAL HARVESTED
** KER'S (1980) BIOMASS EQUATIONS

TABLE 3 COMPARISON OF CHIPS PRODUCED TO BIOMASS ESTIMATES FROM SAMPLING

OPERATION	OD TONNES ESTIMATE TONNES/HECT.*	OD TONNES CHIPS PRODUCED/ HECT.	PRODUCED ESTIMATED
Thinnings	21.3	17.2	81%
Clearcuts	109.0	55.3	51%

* KER'S (1980) BIOMASS EQUATIONS

TABLE 4 PRODUCTIVITY OF OPERATIONS

ELEMENT	20% TONNES/HR.		CUBIC METERS*/HR	
	Man	Machine	Man	Machine
Harvesting	0.15	0.40	0.75	2.00
Chipping	0.36	0.77	1.80	3.85
	HRS/20% TONNE		HRS/CUBIC METER	
	Man	Machine	Man	Machine
Harvesting	6.67	2.50	1.33	0.50
Chipping	2.78	1.30	0.56	0.26
	CORDS**/HR			
	Man	Machine		
Harvesting	0.20	0.50		
Chipping	0.50	1.00		

* AT 0.2 TONNE/CU M OR 12 LBS/CU FT.

** 1.3 TONNES/CORD AT 20% MC

TABLE 5 RATIOS OF HIGHER HEATING VALUE OF CHIPS PRODUCED TO FUEL USED TO HARVEST, CHIP AND TRANSPORT.

ELEMENT	ENERGY RATIOS		% ENERGY
Harvesting	13:1 to 13.1		44
Chipping	47:1 to 47:1		56
Transport			*

* % OF TOTAL ENERGY IN CHIPS REQUIRED FOR TRANSPORT = 0.92 X KM

TABLE 6 AVERAGE COSTS TO PREPARE AND DELIVER FUEL CHIPS TO HOME CONSUMER (BULK DELIVERY).

ELEMENT	$/MAN HR.	$5/MACH. HR.	$/20% TONNE	$/CU. METRE
Harvesting	7.40	11.[illegible]4	78.46	15.69
Chipping	7.40	7.43	30.20	6.04
Transport			15.00	3.00
Screening				
Drying	7.40		22.20	4.44
Bulk Storage				
Home Delivery		1.25/Km	8.18	1.64
		TOTALS	$154.04	$30.81

TABLE .7 EXAMPLE OF COSTS OF MULTI-PURPOSE FUEL CHIP PREPARATION IN THE FOREST: AESTHETIC THINNING.

ELEMENT	$/MAN HR.	$/MACH. HR.	$/20% TONNE	$/CU METRE
Harvesting	Charged to thinning		0.0	0.0
Chipping	7.40	7.43	30.20	6.04
Transport			15.00	3.00
Screening				
Drying	7.40		22.20	4.44
Bulk Storage				
Home Delivery			8.18	1.64
		TOTALS	$75.58	$15.12

TABLE 8 AVERAGE COSTS TO PREPARE FUEL CHIPS IN THE FOREST FOR ONESELF, ASSUMING EQUIPMENT (EXCEPT CHIPPER) ALREADY OWNED.

ELEMENT	$/MAN HR.	$/MACH. HR.	$/20% TONNE	$/CU. METRE
Harvesting	0.00	3.74	9.35	1.87
Chipping	0.00	4.30	5.59	1.12
Transport			15.00	3.00
Screening				
Drying	0.00	$0.04/kWh	2.00	0.40
Bulk Storage				
Home Delivery		0.00	0.00	0.00
		TOTALS	$31.94	$6.39

TABLE 9 DESIGN INFORMATION SUMMARY

ELEMENT	SPECIFICS	VALUES
As-Produced Chip Bulk Density	Hardwoods	320 kg/cu m (20 lbs/cu ft)
	Softwoods	250 kg/cu m (16 lbs/cu ft)
20% MC Chip Bulk Density	Hardwoods	240 kg/cu m (15 lbs/cu ft)
	Softwoods	200 kg/cu m (12 lbs/cu ft)
Average Volume Expansion Ratios	Solid Wood To Chips	2.6
	Cordwood to Chips	1.7
Forced Airflow Through 2.5 M (8 Ft) of Chips	5 hp axial fan, 500 pa (2 in. wg)	0.22 cu m/sec/sq m (41.5 cfm/sq ft)
Ambient Air Volume Required	To Evaporate 1 Kg of water	418 cu m (14,761 cu ft)
Ratio of Water Evaporation Energy to Fan Energy	May to July, 5 HP Fan	4:1

TABLE 10 SOME DESIGN RELATIONSHIPS

CHIP CONDITION	RELATIONSHIP
Green	Cord = 1.7 Tonnes
Green	CU M = 0.4 Tonnes
20% MC	Cord = 1.2 Tonnes
20% MC	CU M = 0.3 Tonne
Any MC	CU M = 0.6 Cord
20% MC	1000 L Oil = 2.4 Tonnes
20% MC	1000 kWh Elect. = 0.2 Tonne
20% MC	1000 L Oil = 8.5 CU M
20% MC	$1/L Oil = $418/Tonne

2.3. INTEGRATED PULPWOOD AND BIOMASS HARVESTING ON A SUB-MARGINAL TRACT,

J. Ellingsen, Boise Cascade Canada Limited

Introduction

Boise Cascade Canada, Newcastle Division, is operating a 200,000 T.P.Y. kraft pulpmill in Newcastle, New Brunswick. Located within a 25 km. radius of the mill are several thousand hectares of Crown Land leased to the mill and some company freehold.

Currently, much of the forest occupying these acreages is of a very poor quality, having been burned and/or highgraded over a long period of time. However, height/age measurements taken on individual, free growing trees indicate a production capacity of up to 5 m^3 (solid) per hectare per year for these sites. To take advantage of this growth potential, these areas should be clear cut and planted. The current species mix and low volumes per hectare makes this economically impossible today, but if some of the wood volumes could be converted into fuel chips and burned in the boilers at the mill, the economics of carrying out a harvesting operation would be quite different. Thus the current low producing acreages would be converted into acreages producing up to three times more volume of desirable wood species per year. The short term benefits would be jobs created by the harvesting and chipping operation. The long term benefits would be an improved wood supply close to the mill, which would help make the mill competitive in the future, and thus again protect and create jobs.

Project #2056

In the spring of 1983, Boise Cascade Canada Limited entered into an agreement with the Province of New Brunswick and the Government of Canada under the Conservation and Renewable Energy Demonstration Program. Under the terms of this agreement, some 150 hectares of currently inoperable stands would be clear cut, the pulpwood and sawlogs delivered to the pulpmill and local sawmills, and the remainder of the materials would be chipped and delivered to the already existing hog fuel burners at the Mill.

Each separate phase of the harvesting operation was assigned to independent private contractors, namely:

i. The cutting of merchantable softwood and the felling of unmarketable tree species,

ii. biomass processing in the form of chipping,

iii. the transportation of pulpwood, logs and hogfuel.

Harvesting

The harvesting of pulpwood and sawlogs was essentially a separate operation from that of the felling of unmarketable tree species. All merchantable softwood was first cut by the use of the labour intensive manual shortwood or tree length systems. Upon extraction of the merchantable softwood by a forwarder or skidder, all remaining trees and brush were directionally felled to facilitate processing by the chip harvesting.

In the manual shortwood system, all merchantable softwood trees were felled, delimbed, cross-cut and piled at the felling site. Any remaining trees were left standing to be directionally felled after the softwood was forwarded to roadside. The harvesting pattern was designed so that the cutting trails of 15 meters in width and 200 meters in length were arranged perpendicularly to the haul road. The resulting rows of brush, in combination with directional felling of fuel-wood trees, facilitated production for the chipper.

The tree length system was also used on this project. However, it had to be modified so that tops and branches could be arranged in rows for retrieval by the chipper. The merchantable trees would be felled, delimbed and topped manually. A cable skidder would then skid the tree trunks to roadside, where logs and pulpwood was bucked out. The remaining unmerchantable trees were then directionally felled.

Finally, to get an idea of chipper productivity at roadside, all trees in a small area containing no marketable wood were felled and forwarded full tree to roadside with a cable skidder. Also, for part of the project, tops, branches, and unmarketable trees were forwarded to roadside, using a double bunk forwarder with large side stakes.

Chipping

The chipping of residues, in the form of tops and branches and unmarketable species, was carried out at the felling site with a mobile chipper. This chip harvester consisted of a Kockum SMV21 forwarder to which had been added a chipping unit, a power source and a chip bin. The chipper manufactured by Bruks Medaniska A-B of Sweden, is a horizontally fed drum unit which has a maximum tree diameter capacity of 40 centimeters. Power from the air-cooled 200 HP Deutz diesel engine is transmitted to the chipper by a belt and pulley drive system. Material to be chipped was fed into the chipper with a hydraulic knuckle boom loader, and the chips blown into a 17 cubic meter container mounted on the rear of the forwarder. This container, when full, can be lifted 4.3 meters in the air, to facilitate dumping into high-sided trucks. Only one operator was required, and all operations were controlled from the operator's cabin. The chipper was the only unit that was operated on a two shift basis.

Chip Transportation

At a delivery distance of 16 kilometers, one high-sided dump truck was sufficient to accommodate the chip harvester at a level of production experienced during the life of the project. The truck was a Tandem Drive Ford, Model LT800, with a 34 cu. meter chip box. This corresponded to two chipper loads, or some 10 tonnes of payload.

Results

The project started June 27, 1983, and was completed on February 28, 1984. By that time, 135 hectares of low volume stands had been cleared, generating 8006 tonnes of hogfuel, 6539 solid cubic meters of sawlogs and pulpwood, and 2356 man-days of employment.

As expected, man-day productivity in the harvesting phase was quite low, averaging 5.46 m^3 solid/man-day for the manual shortwood system, and 4.61 m^3 solid/man-day for the tree length system. The reason for the low man-day productivity in the tree length system versus the manual shortwood system appears to be the small tree size encountered. Man-day productivity for biomass production averaged 6.31 tonnes/man-day. Total marketable volume per hectare was 48.43 solid m^3, plus a hog fuel volume of 59.3 tonnes per hectare, for a total volume per hectare of 98.0 tonnes. Utilization was high, with 93.6% of total available biomass removed. The chipper production varied from 4.1 green tonnes/PMH when chipping logging residue in the field, 11.47 green tonnes/PMH when chipping logging residue at roadside to 14.46 green tonnes/PMH when chipping full trees at roadside. In combination with a forwarder forwarding brush to roadside, where the chipper alternates between chipping at roadside and in the bush, 7.67 green tonnes/PMH was averaged. Chipper availability averaged over 75% for the duration of the project. Forwarder production of brush averaged 4.3 tonnes/load, and 1.0 load/PMH.

Discussion

Project #2056 demonstrated, that if a market for hogfuel exists, a combination of harvesting and chipping can be a viable alternative when dealing with stands containing low volumes of marketable species. However, the operation described above may be greatly improved if the following changes could be make:

1. Chipper production increased by working together with one of more forwarders.
2. Better directional felling by cutting crews.
3. Trucking system changed. The system used was far from efficient. A container system or spotted trailers would have the potential of greatly increasing the trucking capacity and thus reducing the trucking cost.

One factor, having a great effect on chipper productivity, was the moisture content of the chipped material. During the test period, it ranged from 32.1% MC on a wet basis in August, to 50.4% in January. Since this variation will have a significant effect upon the chipper production in terms of green tonnes/PMH, ways should be found to establish a rate scale which does allow for changes in moisture content.

Finally, a significant side benefit is the fact that these sites can now all be planted without further site preparation.

2.4 INDUSTRIAL RESIDUE HARVESTING IN A NORMAL LOGGING OPERATION,

P. McKinley, Fraser Inc.

The use of biomass as a fuel for industrial use is now a reality. This is exemplified at Fraser where we are burning the wood residue generated at our pulpmills and sawmills to displace oil consumption. In fact, we have even gone to the expense of constructing a $40 million steam line from the Edmundston pulpmill to our Madawaska, Maine papermill to supply a significant portion of their energy requirements. Future plans include the conversion of an additional boiler at Edmundston from oil to wood residue thereby resulting in an increased biomass requirement.

Up until now, most of the supply of residue required for fuel at our mills has been provided for from the wood waste generated at these plants. This is obviously the most economical supply. However, we have been looking ahead to the future when demand will undoubtedly outweigh the supply. At that time, more costly and less convenient biomass supplies, such as residue from logging operations, will have to be tapped providing they are competitive with oil.

Our project was undertaken in co-operation with the Canada/New Brunswick Conservation & Renewable Energy Demonstration Program. The aim was to determine the volumes available and costs involved in retrieving, processing and transporting this material to the user destination.

The project was divided into two completely separate sources of biomass supply from harvesting residue.

The first source being - Biomass supply from the tops and branches of full-tree softwood trees harvested on our logging operations.

The second source being - Biomass supply from the residual, non-marketable hardwood, component or our softwood logging sites.

Due to circumstances beyond our control, we were unable to carry out the first phase of the project this past year. We are, however, optimistic that we will be able to conduct the softwood branches and tops chipping this spring and thereby fully evaluate the potential of this residue as a biomass fuel. The second phase of the project, involving residual hardwood, has been completed and it is that aspect that I intend to discuss in some detail.

The nature of the majority of forest stands we harvest results is a significant quantity of low-quality hardwood left standing after the clear-cutting of the softwood component of the stand. This volume averages approximately 40 m^3/ha or for the benefit of the un-metricized people in the audience roughly 5-6 cunits/acre. Approximately 10% of this total hardwood volume can be recovered as sawlogs. The remaining 90% is of pulpwood quality, for which unfortunately, there are few marketing opportunities due to the remoteness of the wood from potential users.

In our project, we harvested the residual hardwood in full-tree form (i.e. including branches and tops) using power saws and conventional choker skidders to bring the trees roadside. From there all the merchantable sawlog material was recovered using a Mor-Bell logger and bucking crew. All sawlogs produced were piled and subsequently hanled to a local hardwood sawmill. In addition to the sawlogs, we also sorted out odd length pieces of what we called oversize pulpwood. This is actually the non-sawlog material that is over 24" diameter and as such, cannot pass through the chipper that was used on the opertion. All remaining hardwood was then forwarded to the Morbark 22" chipper using a John Deere 740 grapple skidder.

The chipper processed the full-trees and the resultant chips were blown into waiting 45' to 50' tractor trailer vans. A notable restricting factor to chipper production was the severe branchiness and crookedness of the hardwood trees. This problem is particularly emphasized in many of the yellow birch trees processed which tend to bear a significant resemblance to apple trees. To remedy this problem, it is necessary to place a man with a chain saw at the chipper. This man can trim the crooked pieces and large tops sufficiently to allow the chipper to process them.

In our case, the hardwood full-tree chips were transported to the Fraser Pulpmill at Atholville, New Brunswick for use as a hog fuel in the boilers. Since transportation cost is basically a straight line function of distance, we would have preferred to transport the material to the much closer Edmundston Pumpmill. However, circumstances beyond our control prohibited this.

As can be appreciated, the entire operation was carried out on an industrial scale, producing approximately 4,600 t of hardwood full-tree chips from a 150 ha. area. This is an important consideration if we are to properly evaluate the economic feasibility of operations of this nature. We feel that the results are very realistic and indicative of what should be expected if residual hardwood on normal logging operations are to be used as a large scale source of biomas fuel. Undoubtedly, the most important aspect of the project is the resultant delivered cost of the material and the comparison of that cost to the cost of the fuel it could replace ... i.e. oil!

In examining the costs involved, we can differentiate them into three distinct cost elements:

(1) Harvesting the hardwood

(2) Chipping the material

(3) Transportation to end user

Actual costs are as follows:

CUTTING - $16/T - Broken down to $10/T direct costs and $6/T overhead costs (i.e. royalty, scaling, accounting, supervision, etc.)

CHIPPING - $14/T - Chipper, skidder, men, etc ...

TRUCKING - .085 T/km @ 166 km - $14/T

Rather than simply adding together the costs we experienced and arriving at a bottom line cost, we would propose a somewhat different approach. At Frasers, we are in the business of growing and using softwood. As such, the hardwood residuals left standing after our softwood harvesting operations are a severe hindrance to site preparation and subsequent planting operations. In light of this, I feel that the practice of charging all hardwood removal harvesting costs against the full-tree chips can be questioned. In fact, it may be more reasonable to charge these costs against the silviculture operations. The silvicultural benefit resulting from hardwood removal (i.e. reduced site prep and planting costs) is something in the order of $50/ha or $1/T.

Or course, all this is simply a matter of accounting precedure and as such, is at the discretion of the particular organization undertaking a program of this nature. Another accounting issue up for dicussion is what associated overhead costs should be included in bottom line costs. Nonetheless, it is important that the accounting procedure used in arriving at bottom line costs is well understood.

From our experience, a roadside cost for hardwood full-tree chips (i.e. harvesting & chipping) of approximately $30/T was realized. This would be reduced to $14/T if we assume the actual hardwood removal to be a necessary silvicultural expense. If we assume a hauling distance of say 70 km to the user facility at a rate of approximately $6/T, we arrive at a delivered cost of $20/T.

The value of a green metric tonne of hardwood full-tree chips at 50% moisture content in terms of oil displaced is calculated at approximately $40. As moisture content decreases the value of the chips increases to the point where at 40% moisture content, a value of $52/green metric tonne is realized. During summer and fall hardwood full-tree chips of 35% to 40% M.C. are common and during uncovered winter storage the moisture content of these chips can rise to close to 50%.

Even at the high M.C., we are looking at a value of $40/T for material delivered to the mill at a cost of $20/T. It should be stressed that the $20/T cost is based on our experience this past year and assumes a 70 km transportation distance. If we were to undertake a similar operation of this nature again a deliverd cost of $16-$17/T could be accomplished through improvements in operation efficiency.

These numbers obviously paint a rosy picture for the use of residual hardwood trees from our logging operations as biomass fuel. It must be noted, however, that the current market value of alternative biomass (i.e. local sawmill waste) is substantially below the costs we could provide it for from our woods operations. As such, we do not foresee a sudden boom in residue harvesting from our woodlands operations in the immediate future. However, as I mentioned earlier as to why we undertook this project, the not too distant future indicates a demand exceeding the supply of the presently easily available material. At that time, the processing of residue from our logging operation for biomass fuel will undoubtedly become a reality.

3. DISTRIBUTION

3.1 SMALL SCALE TRANSPORTATION, DRYING & STORAGE,

C. A. Short, Univerity of New Brunswick

As Marc Schneider mentioned yesterday, the small scale harvesting project has been supported by the Canada-New Brunswick CREDA Program and was inspired by work on wood chip burning equipment, funds for which were provided by the New Brunswick Energy Secretariat. That work started in 1978. As a result of the success of the work with burners, consideration of fuel supply and means to obtain that supply seemed a logical next step.

In particular and considering the large number of small woodlots in New Brunswick, it was concluded that a useful and appropriate study would be one that determined the technical and economic feasibility of small scale, low capital cost, wood chip harvesting systems. The intent was to find methods of harvesting that could be used by farm operators and small woodlot owners to turn low quality stands into a useful, saleable fuel while clearing their land in order to achieve silvicultural objectives relative to stand improvement. It is important to emphasise, and following Marc's presentation yesterday, to re-emphasise, the significance of small in small scale.

The title of my talk indicates transportation, drying and storage. I'll follow those headings in sequence while splitting transportation into two phases - primary (from forest to processing center) and secondary (from center to consumer).

The costs experienced in our study are as follows:

Cost primary transport - $0.50/green tonne @ 18 km
$18.00/green tonne @ 58 km

Cost to screen, handle and dry is $23/20% tonne

Cost to bag and transport in trailers is $28/20% tonne

Cost trailer delivery with loose chips is $15.40/20% tonne

Cost truck delivery is $12/20% tonne

The impact of increasing the scale of delivery can be seen quite clearly and mirrors the overall relationship between the cost of harvesting chips using large industrial equipment (approximately $20/green tonne) relative to our cost experience which ranged from $104 to $198/20% tonne or roughly $50 to $100/green tonne.

A word of caution!! Do no try to add the various quoted costs to arrive at the delivered cost of screened, dried chips. The figures quoted are either averages or have been adjusted, in the case of distribution costs, to a delivery distance of 24 km. Measured costs vary considerable either way. Refer to the report for specific details and conclusions.

General conclusions are:

1. Small scale operators cannot compete with large scale industrial producers in supplying chips on a retail basis
2. Labour costs amount to almost 50% of the cost of production
3. Do-it-yourself small scale chip production in which labour is not charged for, is cost effective and can result in chips for one's own use - say on a farm or woodlot situation - at about $32/20% MC tonne (25% the cost of #2 oil).
4. We are at an early stage of development with small-scale systems, and have just completed the first season of the full harvest-process-delivery cycle. The bottlenecks requiring attention relate to chipping and drying in order to reduce those costs.

3.2 LARGE SCALE CUSTOM INDUSTRIAL DELIVERY,

W. Torunski, J.D. Irving Ltd.

Having been in the residues business for just over a year, I find myself with just have a limited knowledge of what is going on. I've learned a great deal from the Symposium and I can only hope that these sessions are repeated more frequently. Hence, my presentation will be a "nuts and bolts" observation of what has happened with residues at J.D. Irving over the past year.

J.D. Irving Ltd. has seven softwood sawmills located in N.B., P.Q. and Maine and produces in the neighborhood of 300,000,000 board feet of lumber. This output, needless to say, produces one heck of a pile of hogfuel or residues. Residues for our company include bark, sawdust, shavings, and in the past year, chips from burnt stands.

This hogfuel is sold and transported to buyers from the Gaspé to N.S., N.B. and Maine.

Total production is 335,000 tons or app. 300,000 metric tonnes.

This makes us the largest single supplier of hogfuel in Eastern Canada.

Translated into truck-loads, this represents 10,000 truck loads/yr and $3.5 million revenue for the transportation companies. The main criteria from the producer's point of view is that residue sales be profitable. Because of the limited margins, sawmills must be efficient and maintain minimum handling of the product. Key costs of hogfuel (90 to 99%) are essentially loading costs, if any, and transportation costs.

Obviously, sawmills located close to the buyer are at a distinct advantage. In our case, our sawmills are rather distant and our transportation distance varies from 50 to 225 miles, the average being 110 miles. However, since we have seven mills, supply is assured and distances minimized. For bark production at Chipman we use a shredder. Our other mills use a scrubber before a ring debarker.

Our bark currently is sold shredded or unshredded. The balance unsold is burned in burners. We do not store residues. Sawdust and shavings are blown into hoppers, and thence to trucks. Storage is avoided because of winter freeze-up problems.

The success of a large operation such as ours depends on timely delivery of the product and our ability to meet our customers' specifications.

Some customers prefer pure bark, shredded or unshredded. Other preferences include bark-sawdust mixtures (20% maximum sawdust), bark-shaving-sawdust mixtures, and pure sawdust. Note that shavings alone are not economical to transport because shavings loads are limited to 16 tons. Other customers' specifications are generally uniform:

1) Must be under 55% moisture content

2) Must be clean, ie. free of sticks or rocks or foreign objects (eg. strapping)

3) Deliveries must be timely

It is imperative that producers of hogfuel maintain these specs because of the serious consequential problems which may rise, for example jam-up of feed systems.

Types of trucks

We use conventional tandem or triaxles, with 50' triaxles on more distant runs. Self-unloaders, with walking or live floors of various types, 96 - 102" wide and 50' long are also used. We have used 14' high self-unloaders from Nova Scotia with success. These trucks unload a payload of 30-35 tonnes in 15 minutes. We have also employed a side dumper, and we use the Peerless dumper with limited loads of 12 - 15 tons for shorter distances.

Problems with self-unloaders are generally related to hydraulics or freeze-up of the load. Blowing exhaust through the load may solve the freeze-up problem, but this needs more study.

Two problems related to transport in general should be mentioned. First, road restrictions are in place when hogfuel is in highest demand. Second, scheduling problems often arise because unloading at buyer mills is not generally geared to heavy input, and mills do not want us to dump in their yard as this leaves them with extra handling.

Notes for the Future

1. The residue industry definitely needs the stability of long term contracts.
2. We must truly maximize loads by maximizing BTU Values. That is, we must look at reducing moisture content with minimum additional costs.
3. For rail delivery, the problem of unloading must be solved.
4. Competition from other buyers must be watched. Namely, the demand for shavings and bark for particle board, the demand for shavings by the poultry industry, and the demand for sawdust by the furniture industry.

3.3 MEDIUM SCALE DISTRIBUTION,

J. Hornby, J.D. Hornby Ltd.

Prince Edward Island is not generally recognized as a wood producing province - indeed, for a great many years the Dominion Bureau of Statistics, or StatsCan, as they are now called, completely ignored the admittedly small volumes of sawlogs and pulpwood we were producing. And it usually comes as a surprise to most people to learn that, of our 1.2 million acres 680,000 are forested. Certainly not a forest base to shake the international market, but enough to have a real influence on our provincial economy ... always providing, of course, that we utilize it.

And properly used the Island's small forest base could be a real advantage, not only to PEI but to other parts of Canada as well.

If we get the encouragement, Provincially and Federally, that we need, we can set up biomass utilization systems in PEI which could serve as base programs for larger operations in other provinces.

In PEI 90% of the forest land is privately owned, and in our search for utilization of biomass a lot of effort must be directed to the education and assistance of our woodlot owners. With only 10% of forest under public control, any larger scale forest industry that does not have the co-operation of the majority of the private owners is bound to be a disaster.

In this regard, I had an interesting experience a few years ago. We were working the Hahn Harvester in the eastern part of the Province, and had just finished one lot when a man came to me and said he had a woodlot he wanted us to cut. I looked at it and found a young, vigorous stand of hybrid red/black spruce; and much as I disliked turning business away I suggested he not consider cutting for a number of years. He told me if I didn't cut it, he would bulldoze it -- he wanted the land for agriculture. So I cut it.

While we were doing this lot I roamed the area and saw a stand of fir about ready to fall down -- obviously over-age and afflicted with butt rot, with some stems already tottering and jack-strawed. An old lady in the nearby village owned the lot, and when I suggested to her that I could salvage a good portion of the wood she chased me. No one was going to touch her precious trees. She, like many of our woodlot owners, felt the trees were immortal.

Agriculture has been in use for thousands of years, but very little silviculture has been applied to our forests. Left to herself, Mother Nature does about the same job in managing the forest as she would in growing crops if no agriculture were practiced.

The way forests in general are being handled, or mis-handled, is like standing at your back door in the spring, closing your eyes and flinging a handful of seeds in the direction of your garden with the expectation of harvesting a crop of vegetables in the fall. Government can control public lands, but it is going to take a big effort to educate private owners in the value of silviculture.

With high-grading and budworm onslaughts our PEI forest now has a greater potential for chips than it has for round wood, and in 1977 the Provincial Government asked me to conduct a chipping experiment using an 18" chipper matched with my Hahn Harvester.

Using four powersaw men and two cable skidders we averaged, in spite of our ignorance and stupidity, about 40 tons/day. We weren't too bright, I have to admit -- but we weren't alone. None of us had ever seen a chipper before. The machine arrived in PEI with no one who knew anything about it, and no instruction manual to help us. The first time we changed the knives it took us two hours.

In any case, this effort was considered highly successful, but the whole thing went into limbo until 1981 when the Government's Energy Corporation decided to install a wood-chip buring furnace in Montague Hospital.

That year I bought a used 18" chipper and we started to produce 2,000 tons of whole tree chips -- a year's supply for the new chip furnace.

Using two powersaw men and two cable skidders we averaged 45 tons/day -- which would have been higher except we got into fall weather, and spent a lot of time pushing and positioning chip trucks.

These trucks were ordinary dump trucks with plywood sides as high as highway regulations would permit -- they had a capacity of six or seven tons each. We also had a dump trailer, with plywood sides, which took nine or ten tons.

For the month of December, 1982, we leased a feller buncher and a grapple skidder, and with just a three man crew, including the chipper operator, on some days we did 85 tons; but due to excessive downtime, our daily average for the month was 55. Also we were working in December when it rained, snowed and froze -- sometimes all at the same time. And the reason we were working in December was because it took us four months to persuade the PEI Government to sponsor the experiment.

But it did convince us that, for hot logging, this was the way to go. Our people worked quite happily in abominable weather -- everyone was in a heated cab in shirt sleeves. We worked steadily on days when it would have been impossible to work men on the ground. Delays due to weather were chip trucks getting stuck in mud or snow, and and having to divert the skidder to push them clear.

The following month, January' 83, we used the same equipment to cold deck about 1,000 tons of whole trees. This was experimental: we felled with the feller buncher, skidded with the grapple skidder and piled with the loader to heights of about 12 feet.

The object was two-fold: one, to get a cost figure on this type of operation as a raw material storage system for eventual chip production; and two, to find out what effect the cold deck would eventually have on the moisture content of chips produced from it.

The cold decks were chipped last fall and moisture content ran in the mid to high 30's, which made the Hospital equipment very happy. The year before, in the hot logging operation, the moisture content showed about 43%.

Although it seemed like unnecessary work to pile trees in a cold deck, and then eventually pull them out of the cold deck and feed them into a chipper, it was felt that it would be worthwhile to have a ready supply of raw material available in a landing at times when it would be difficult to fell and skid.

Cold decking would seem to be a better system to handle the extraction material from stand improvement work; instead of the present method of cut, top, limb and slash into 8' bolts -- which usually results in a product of little or no merchantable value. Cold decking would also cut the operator's work in half, and nearly double his volume -- which would mean an efficiency improvement factor of almost four.

PEI's Forestry Department is doing a great job of stand improvement, and this work is obviously aimed at up-grading our forest to the point where it will one day produce more merchantable wood than chip material. With this in mind, and since we are trying to persuade large facilities to convert to woodchips, I believe it is not too soon to plan the establishment of energy plantations.

Given PEI's admittedly marvellous climate and terrific soil, the growth rate of hybrid popular, for example, in an energy plantation would be nothing short of phenomenal.

This would mean that we could guarantee fuel supplies in perpetuity, and some day in the next century our wood chips would be provided by energy plantations and the residue from merchantable wood operations.

And, with an energy plantation, the operating costs would diminish year by year, comparatively speaking -- because we'd always be working from established roads and landings, and harvesting could be done with something like an oversized haymower.

If we adopted the cold decking system, chipping could be done on a custom basis with the chipper moving from area to area. This would mean that people from all over the province could participate in the chipping program; and, since they wouldn't be holding up either the chipper or the chip trucks in the construction of their cold decks, they could work at their own speeds, with equipment as unsophisticated as a horse.

This might result in somewhat lower production and maybe higher costs than hot logging with machines, although this would bear further study; but one of the purposes of this whole exercise should be to increase exployment, and this is a good way to do it.

Even in PEI with its small forest base, we are harvesting 110,000 cords of fuelwood annually; and this is replacing sixteen million dollars worth of imported oil -- <u>every year</u>. In addition, we estimate that 300,000 tons of biomass are available yearly; and if, as some say, a ton of green chips is equivalent in BTU's to a barrel of bunker C oil, who can justify abandoning 300,000 barrels of oil every year? It's almost like having a small oil well and refusing to pump it.

It seems to me, too, that in all the feasibility studies done on the viability of biomass as a fuel, the very important multiplier effect is being ignored; in that it is calculated that, out of every dollar spent on energy, 90 cents stays at home if a local fuel is being utilized.

Add to this the amount of money spent on oil subsidies and U.I.C. payments, in the contest with imported oil, biomass must be a hands-down winner.

But all of this presupposes the sale of a much greater volume of chips than is now possible in PEI. All of our experiments continue to indicate that whole tree chips as an alternate fuel are really not economically feasible unless they can be produced in volume. And for an operator to gear up for high volume low cost chip production he would have to be working on an annual quantity of about 10,000 tons. Right now the PEI Government is considering a wood chip furnace for the oil PEI Hospital, with a steam line over to the Provincial Government offices -- and this installation would require 8,000 tons a year, which is just what we in PEI need to get our wood chip industry off the ground.

Gentlemen, the installation in Montague Hospital is running like a watch, and I'm told the operting cost is one-third the cost of oil.

I know of a 3,000 acre woodlot in Kings County which contains very little merchantable wood, but it could produce volumes of chips. This lot, even if gradually clearcut, could support the proposed 8,000 ton facility in Charlottetown for 30 years -- and if reforested as it was cut, it could supply the big unit in perpetuity.

We have the need, we have the equipment, we have trained people eager and anxious for work -- and we sure have the resource.

4. COMBUSTION OF PARTICULATE FUEL

4.1 WOOD CHIP FURNACE DEVELOPMENT AT THE UNIVERSITY OF MAINE

Dr. Norman Smith, University of Maine, Orono

Development of wood chip fueled furnaces and boilers has been underway at the University of Maine for ten years. Recent work has focused on widening the output range of the burners and on developing a unit which is to be commercially produced in quantity.

Development of automatically controlled wood chip burners began at the University of Maine in 1973. The chip burners were envisioned as retrofits to existing boilers and furnaces to replace oil burners. Operation was intended to imitate an oil burner, with ignition on call of a thermostat and complete shutdown when the call for heat ended. Logging residues, which even then amounted in Maine to over two million tons per year, were expected to provide the fuel with possible use of "puckerbrush" or cultivated brush crops if these proved economical.

The chip burners aroused a great deal of interest and though acceptance was slow at the outset, several units in the 200,000 to 500,000 BTU/hour range were designed and installed in various commercial and public buildings. However, problems of fuel supply, handling and feeding, along with the cost and complication of the automatic control system were thought to preclude development of an economical, reliable, residential size unit which could be operated with a minimum of technical knowledge and supervision.

In early 1979 a miniaturized chip burner was designed which used a slightly modified stack switch, intended for use with an intermittent ignition oil burner, as a control. These switches could be purchased as rebuilt units for as little as $25. This development, along with introduction of a "safety loop" in the control circuit which incorporated limit switches to shut down fuel supply if a blockage occurred and a thermal cut out to shut down the unit

in case of burnbacks or downdrafts, resulted in the installation of several test units in residences. There were capable of producing 60-100,000 BTU/hour.

A pilot scale fuel processing facility was built under a USDA/DOE grant in 1981 and a flame sensing control was perfected and used on all installations made during the next two years. Developing a low cost reliable, long life, electric igniter to replace oil burner ignition proved more difficult, and as a short term measure a method of using intermittent bursts of fuel feed to maintain a standby fire was developed. This was originally only intended to serve as a stop gap measure until the igniters were perfected. However the timer-controlled standby fire operation proved so reliable that all electrically ignited units have been built with this as an alternate operating mode. Maintenance of a standby fire takes from six to ten minutes of fuel feed per hour, depending on fuel moisture content and draft conditions.

Over the past three years the chip burners have been steadily simplified and miniaturized. For example, several fireboxes with grates only 4" X 3" have operated domestic hot water heaters and a self contained space heater. This unit has been used at a number of demonstrations and is now heating a remote classroom on the University campus. Combustion intensity has been doubled by use of tuyeres to inject air at pre-set levels in the fireboxes. Heat output rates of 5,000 BTU/hour. in of grate are regularly attained on these small units. The standby fire operating mode is used on small units to avoid the cost of flame sensing control and automatic ignition. A standard 'fan and limit' switch is used in the stack to shut down the burner if the standby fire is lost.

There have been two major thrusts in the past year, to widen the output range of the burners, and to develop a commercial version of the residential size unit with the simplified control system.

In the summer of 1983 the largest UMO chip furnace to date, rated at 1.5 million BTU/hr, was installed in the University's Service Building where it fires a 65 HP Kewanee boiler. The system burns approximately 420 lbs of green chips/hour. These are delivered by van, which is left parked at a loading dock, and offloaded periodicallly with a Bobcat loader into a bin holding a one day's fuel supply. It was decided to try direct, high temperature, continuous fuel drying using flue gases in this design. Experiments with small batches of chips placed in a drying oven showed that at 250-325°F, moisture content could be reduced from 42-20% in 5-15 minutes. This finding was used in the design of the high temperature dryer. Green chips being fed from the fuel bin to the firebox drop into a 30-inch diameter drum where a 15-inch deep bed of chips is maintained and stirred. Average residence time for the chips is around 15 minutes. Dried chips are removed from the bottom of the dryer by a rotating arm which draws them to the center of the drum from whence they pass into a horizontal auger which carries them to the firebox.

Approximately 500 c.f.m. of flue gas, roughly 30% of the total leaving the boiler, is passed through the dryer. Gas temperature entering the drum is maintained just below 350°F by dilution with ambient air. Gas leaving the dryer is at around 110°F and fully saturated. Gas flow through the bed is only 100 c.f.m./ft^2, approximately 1.5 ft/second, and very few particles of fuel are picked up from the wet surface of the bed.

During the fall of 1983 fuel typically entered the dryer at 40-43% moisture content (wet basis) and left at 28-35% depending on flue gas temperature. The dryer regularly removed 40-50 lbs of moisture per hour from the fuel, and an 80 lbs/hr removal rate was once attained. Later in the winter when the chips were received frozen, often at temperatures around 0°F,

performance of the dryer changed drastically. Of the 60 - 70,000 BTU/hour given up by the flue gas passing through the dryer approximately 40,000 BTU was used in thawing water in the chips and raising the water temperature to 110°F; approximately 10,000 BTU was expended in heating the wood and only about 10,000 BTU was used to evaporate moisture. However 60 - 70,000 BTU/hour was still being retrieved by the dryer and therefore was not required in the firebox to heat the frozen fuel.

Overall efficiency of the unit has varied from 70 - 80% over the test period. Over 2,200 hours of testing had been carried out on the furnace and drier by early February 1984. The chip burning system provides base heating for the Service Complex and can handle the entire load down to approximately 10°F in calm weather and around 20° during windy periods. An oil fired boiler backs up the chip fired unit as required. At the end of January 1984 18,000 fewer gallons of oil had been burned in the building than during the previous winter. Projected for a full season this represents a fuel saving of around 30,000 gallons of oil from a total consumption of 55,000 gallons. Additional labor is needed to run the chip burner and net savings will not be known until the end of the heating season.

A sub miniature chip burner with a grate area of only 5 in^2 (2" X 2 1/2") is being tested as a domestic hot water heater. The heat exchanger is a 20 lb propane cylinder mounted on its side directly above the chip burner. Fuel enters the burner through the firebox side. Feed rate is approximately 18,000 BTU/hour. This represents a recovery rate of 20 gallons of 150°F water per hour, adequate for any residential system. Stack temperature varies from 210 - 240°F and the unit runs with around 300% excess air. Efficiency is approximately 80% as the low stack temperature counter-balances the effect of the excess air.

Alternate Energy Systems of Sherborn, Massachusetts, has been licensed to manufacture the University of Maine designed wood chip furnace, and is producing an 85,000 BTU/hour self-contained hot air unit. Custom built chip burners in the 200,000 - 1,500,000 BTU range are also available.

4.2 WOOD RESIDUE COMBUSTION INSTALLATIONS IN N.B.

D. Gorman, ADI Ltd.

We have been asked to review with you some of the wood-fired heating plants currently in operation in the province. There are many establishments using wood residue as fuel ranging from the very small, used in schools and small industrial applications, to the very large, as are found in the paper industry. Four plants have been selected for review; these are: the Madawaska Correctional Centre, Finnigans Greenhouse in Rogersville, the Maritime Forest Ranger School and the University of New Brunswick heating plant extension in Fredericton. All plants have wood-fired boilers utilizing wood residue as primary fuel.

This paper examines the plant equipment required for receiving, storage, reclaim and transfer of wood fuel to the combustion chamber, the boiler and its direct auxiliaries. A brief summary will be provided as to the performance of each plant since commencement of operations.

Finnigan Greenhouse - Rogersville

The 100 hp wood-fired boiler is the sole source of heat for the half acre greenhouse, and in order to improve its reliability, an oil gun was included to automatically maintain load, should the wood fuel not be available or trouble develop in the wood handling and feed system. The greenhouse is used to produce tomatoes and cucumbers.

The boiler was installed in 1978 and has worked reasonably well since that time. It uses residue from an adjacent sawmill, and since this mill does not operate a full twelve months per year, it was necessary to provide for storage of some wood fuel. The owner has since added a chipper to prepare chips from slabs and roundwood, should the fuel not be available from the sawmill.

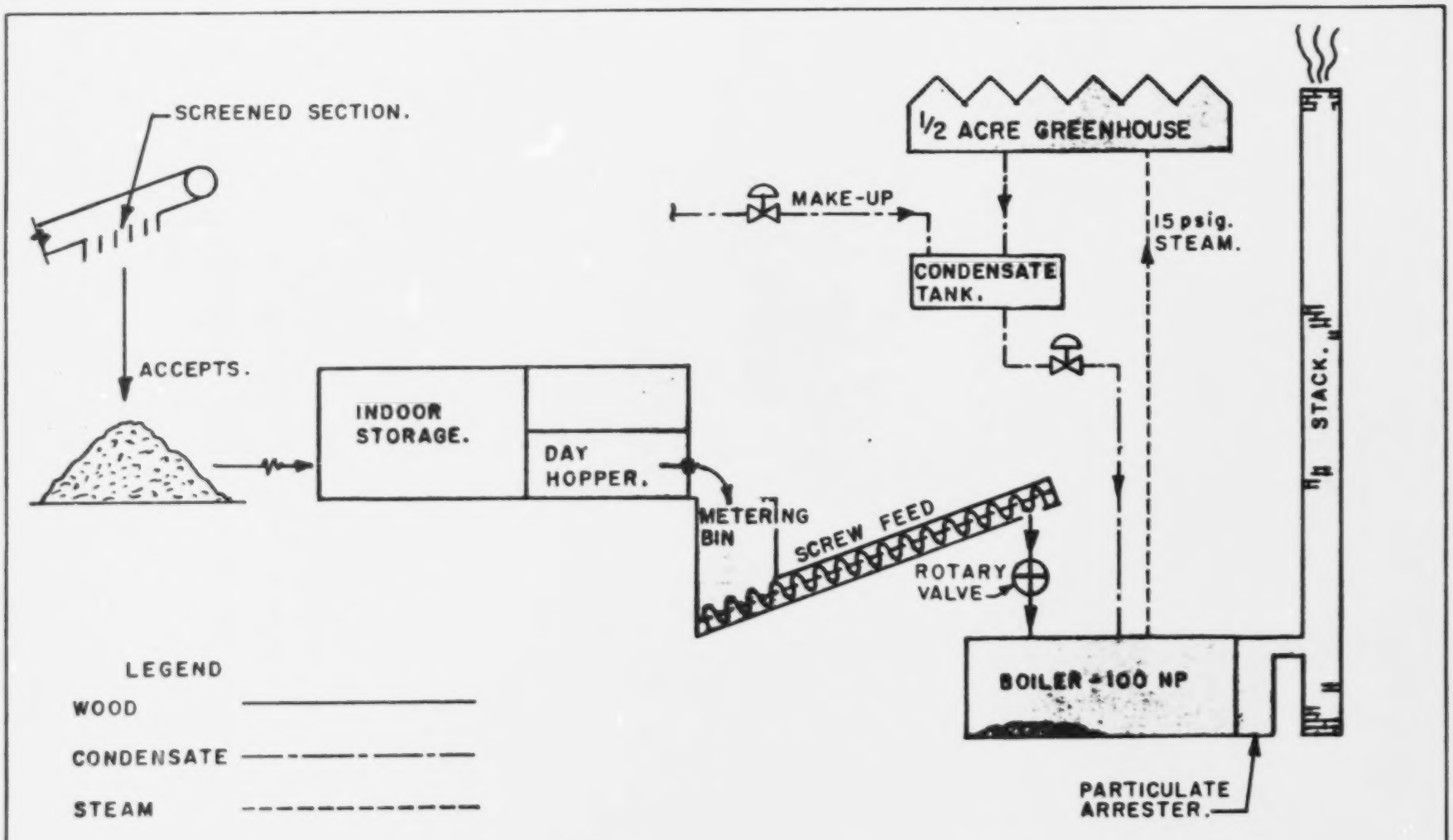


FIG. 1

Job: WOOD ENERGY SYMPOSIUM - FEB. 26 to 28, 1984	ADI Limited — Engineers, Architects, Management Consultants, Planners, Surveyors (506) 454 4491, 1115 Regent Street, Fredericton, N.B.	Drn. by: RCF	Scale: N.T.S.	Date: 84-01-24
Drawing: FINNIGAN GREENHOUSE - ROGERSVILLE, N.B.		Drawing No.: 457-74 FIGURE 1		

ADI 2-107

The boiler is of the fire-tube, three pass design. It operates on the guarded-plant concept such that on occurrence of any trouble, the unit shuts down and an alarm is sounded in the operator's home. The boiler is checked out by the operator, the deficiency corrected, and the system restarted, on wood fuel preferably, but on oil if corrective measures cannot be made quickly. (See Figure 1).

The wood residue from the sawmill is normally fed to a teepee burner. We were permitted to install a screen in the conveyor such as to permit properly sized wood particles, of about 3/4" on a side and less, to fall into the "accepts" pile. This material is then transported by an off-road vehicle to the storage area at the greenhouse, loaded into the day-bin by a front-end loader, and withdrawn from the day-bin by bottom screws into a metering bin. The fuel is reclaimed from the metering bin by screw feeders driven at a rate proportional to boiler demand and transported to the boiler via another screw where it enters the top of the boiler through a rotary valve.

The hot gases pass through a particulate arrestor on the back end of the boiler, with the particulate collected and returned to the fire box. Ash is removed by hand.

The boiler produces steam at 15 psig (105 kPa) for distribution through the greenhouse.

The boiler and auxiliaries were supplied by JIMARCO of Toronto; the installation of the boiler and erection of foundation and support structures was performed by the owner's forces.

Madawaska Regional Correctional Centre

The correctional centre is located just outside of Edmundston. It was originally designed with two hot water oil-fired burners of 100 hp each. These units were located inside the centre and supplied the heating and domestic hot water needs for the establishment. Provision was made in the design for possible addition of a wood-fired boiler outside the centre to operate in parallel with the two existing oil-fired units.

Following a review of loads experiences over the period since its inception, a decision was made in favour of a 50 hp boiler, using wood chips as a fuel.

The natural terrain adjacent to the centre was sloped sufficient by to permit installation of the wood storage bin into a hillside such that transport vehicles could off-load directly into the bin.

As the flow diagram indicates (see Figure 2) the wood chip fuel is withdrawn from the storage bin using a scraper bottom discharging into a collector screw conveyor. The fuel is raised into the stoker feeder by means of an inclined screw. The stoker feeder carries the fuel into the underside of the combustion chamber where it flows upwards and spreads over the hearth. The overfire combustion air is admitted through pipes located around the pile and through openings in the hearth under the pile.

The pile-burning concept with the very tranquil form of feed reduces the risk of particulate carryover. The hot exhaust gases of some 500° to 600°F are passed through a dust collector and through the Induced Draft Fan to the stack.

There is an automatic ash handling system which clears the ash from the dust collector on a timed basis. The ash is removed from the combustion chamber by raking into the ash pit below the grate and activating the ash screw manually.

The plant is equipped with controls for guarded-plant operation. The centre continues to operate with one qualified stationary engineer on a call basis. He makes an inspection of the facilities daily and looks after routine servicing. An alarm is connected into the main security centre, and should any "off-limit" conditions develop, the security personnel contact the plant custodian.

The plant was commissioned in 1982 and has operated successfully since that time. It has, over that period, supplied an estimated 80 percent of the centre's heat and domestic hot water requirements.

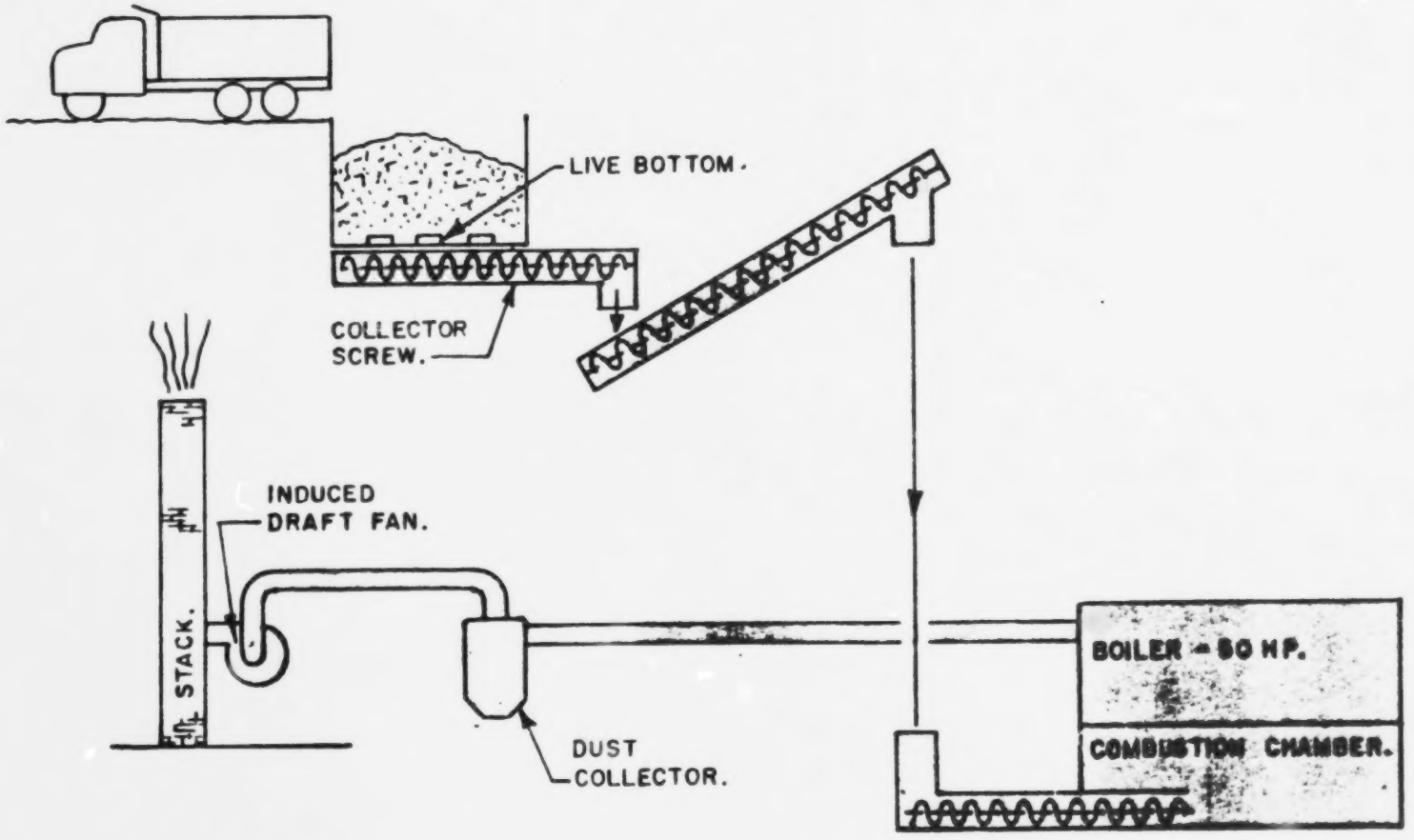


FIGURE 2

Job: WOOD ENERGY SYMPOSIUM - FEB. 26 - 28, 1984	ADI Limited — Engineers, Architects, Management Consultants, Planners, Surveyors (506) 454 4491, 1115 Regent Street, Fredericton, N.B.	Drn. by: RCP	Scale: N.T.S.	Date: 84-01-25
Drawing: FLOW DIAGRAM MADAWASKA REGIONAL CORRECTIONAL CENTRE		Drawing No.: 457-74 FIGURE 2		

ADI 2-107

The equipment was manufactured and supplied by ANGA VARME of Canada. The installation of the plant and building was done by Brunswick Construction Ltd. of Edmundston. The total cost of facilities was $270 000.

Maritime Forest Ranger School

The Maritime Forest Ranger School burned wood in stick form from the date of commencement in 1946 to 1977, at which time the boilers were in need of replacement. It was decided to continue with wood fuel, with the change that the system be automated to burn wood chips with only minimum supervision.

A 100 hp wood fuel boiler was installed, with a 100 hp oil-fired (#2 oil) boiler to serve as back-up.

The wood-fired boiler--of the water leg type--was manufactured and supplied by the MATHESON Company of Nova Scotia. The grate section, including the combustion air feed, was designed by ADI Limited. The boiler produces steam at 15 psig for use in heating the complex and supplying domestic hot water. A heat exchanger is provided in the steam plant to transfer heat from the steam to water for distribution around the campus. The plant was commissioned in 1978 and has performed well since that time with only minor problems. The boiler is of adequate capacity to supply the full needs of the school complex. (See Figure 3).

The wood fuel is obtained as slabs from the school's sawmill, as residue roundwood from the school's forestry training area, and some from a local sawmill. The heating plant has a chipper and screen for preparation of the residue into acceptable chip fuel.

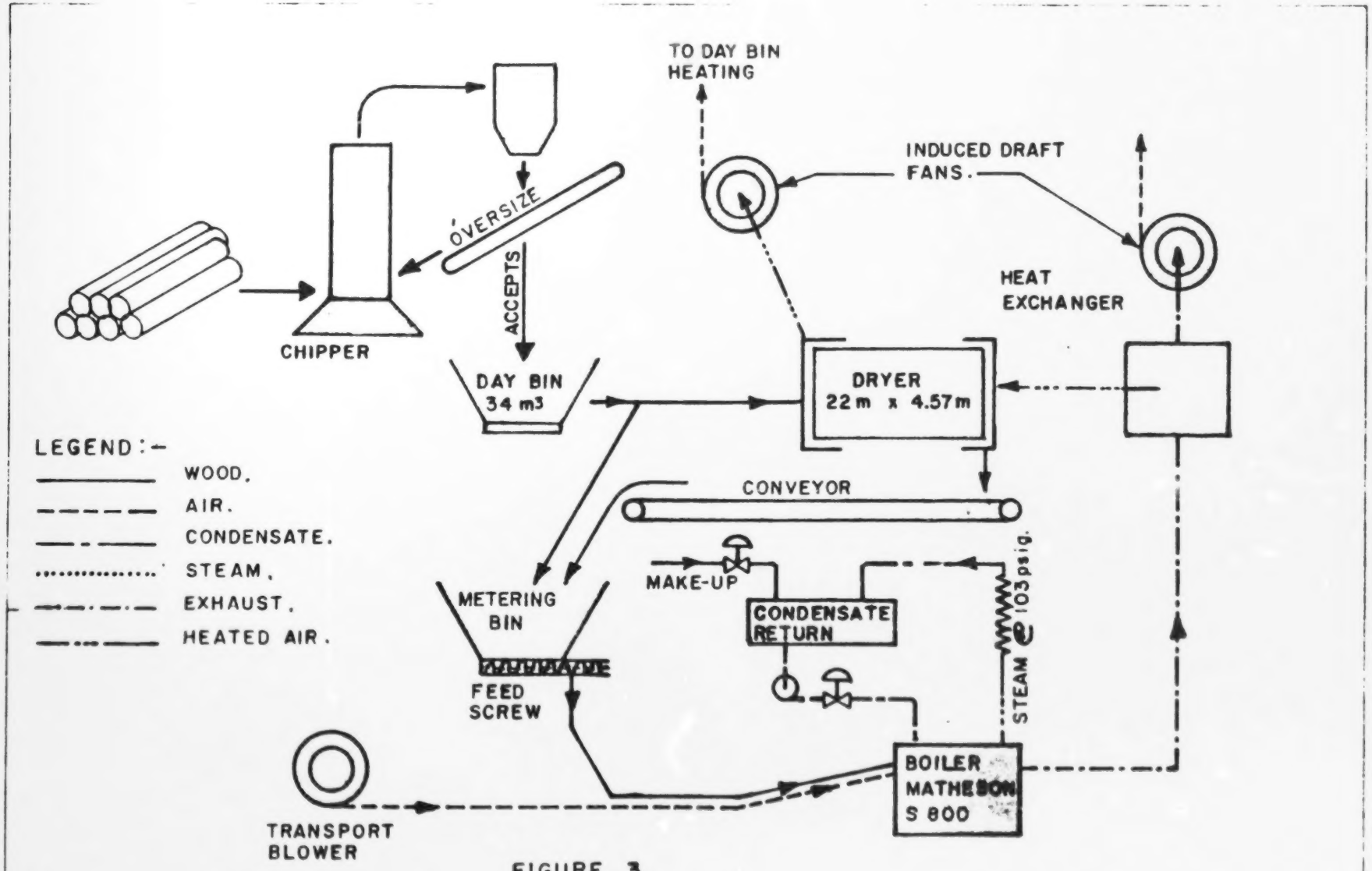


FIGURE 3

WOOD ENERGY SYMPOSIUM – FEB. 26-28, 1984

WOOD HEATING SYSTEM SCHEMATIC
MARITIME FOREST RANGER SCHOOL

ADI Limited

RCP | N.T.S. | 84-01-27

457-74 FIGURE 3

The wood residue is stored in a day-bin from which it is withdrawn by means of two continuous chains. The fuel is directed, at the end of the chain conveyor, into a dryer or directly into the metering bin. The fuel, as directed into the rotary type dryer, is exposed to a hot air stream (150°F) where some drying takes place. Under normal circumstances, the dryer is not required, since the wood fuel is in the order of 35 percent to 45 percent moisture content (wet basis) and, therefore, suitable for firing. The heat for the dryer is supplied from the hot gas discharge, with the exchange accomplished through a tubular heat exchanger. The wood fuel from the dryer is transferred to the metering bin by a light conveyor.

The wood fuel directed into the metering bin is withdrawn by means of a speed-regulated (HIGH/LOW) screw conveyor into a pneumatic feeder for transfer into the combustion chamber of the boiler. Some of the fuel burns in suspension, but the bulk of it burns in pile on the hearth. Ash is removed by hand from a door in the front of the boiler.

The plant has operated over the years almost exclusively on wood fuel with minimal supervision. The operating staff consists of one stationary engineer who also assumes other duties in the complex.

UNB Heating Plant

The plant consists of two oil-fired boilers, each having a rating of 120,000 pph, and one wood-fired boiler having a capacity of 40,000 pph. The wood-fired boiler has just been installed, and we do not as yet have much experience in terms of boiler performance. We examined three similar boilers of the Towerpak design as manufactured by Babcock & Wilcox, all on wood firing, prior to purchasing this boiler.

It is intended that the wood-fired boiler operate on base load in parallel with one of the oil-fired boilers; the oil-fired unit will serve to take all load swings. The wood-fired boiler will operate at maximum load such as to displace as much #6 oil as possible.

The maximum load at the plant is approximately 100,000 pph; the minimum summer load is in the order of 10,000 pph. For three or four months of summer, the wood-fired boiler will carry the load under the control of the plant master. Its turndown is four to one, and no difficulty is foreseen in operating at this low load.

The wood fuel is being supplied by a local lumber processor who will be drawing on residue available from five sawmills. Provision is also made for using forest residue, should such be a requirement. The quantity of wood fuel required per year is some 45,000 tons based on 50 percent (wet basis) moisture content.

The plant is designed to receive the wood residue, transfer to storage, reclaim from storage and feed into the boiler at a feed rate proportional to the boiler heat demand. (See Figure 4).

The wood feed into the boiler is via an underfed screw stoker--which is arranged to force the wood fuel up through the centre of the grate. The wood spreads over the grate and burns in pile; this makes for a tranquil admission of fuel, thus minimizing the tendency for particulate emissions.

The grate is of the pinhole type, with underfire air fed up through the pile; overfire air is admitted above the grate and the tertiary air, in small quantity only, above the overfire air. The air, after passing through the tubular air heater, enters the boiler at a temperture of 300°F to 500°F.

The exhaust gases, on leaving the tubular air heater, pass through the dust collector of the mechanical type (complete with 86 separate collector tubes). Three fans are provided--the Forced Draft, the high-pressure overfire (tertiary) blower, and the Induced Draft Fan.

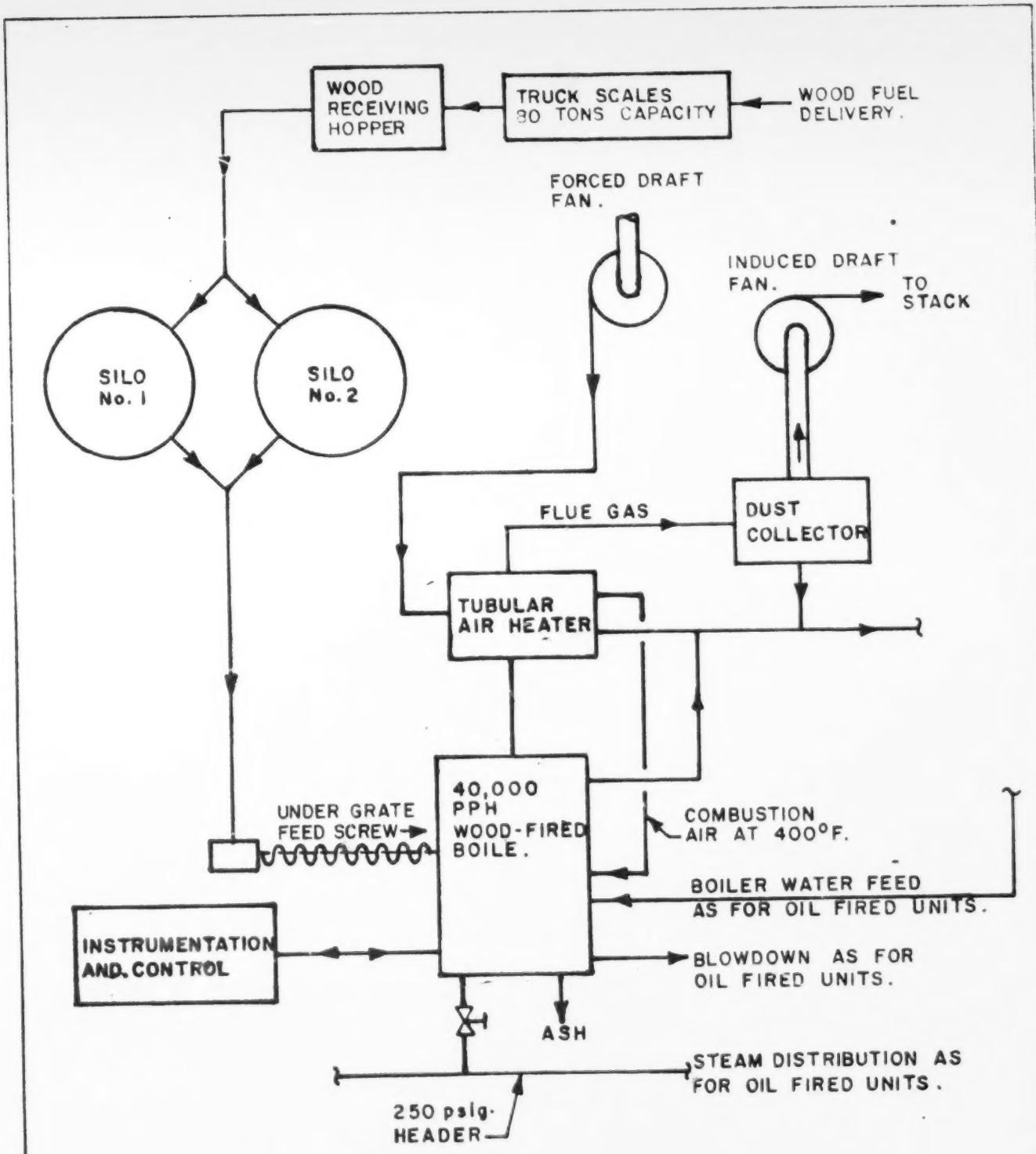


FIGURE 4

Job WOOD ENERGY SYMPOSIUM FEB. 26-28, 1984	ADI Limited Engineers, Architects Management Consultants Planners, Surveyors (506) 454 4491 1115 Regent Street, Fredericton, N.B.	Drn by RCP	Scale N.T.S.	Date 84-01-30
Drawing FLOW DIAGRAM WOOD FIRED BOILER - U.N.B. HEATING PLANT		Drawing No. 457-74 FIGURE 4		

ADI Z-106

Soot blowing is provided through use of six rotary type blowers on the generating tube bank and one retractable blower in the tubular air heater.

The water feed, the steam distribution, blowdown, testing and drains are all conventional.

The plant had a capital cost of $2.4 million, and a total of five assistant operators have been added to plant staff to monitor fuel deliveries, wood feed, maintenance, and control of all facilities of the plant.

4.3 INSURANCE AND CERTIFICATION OF RESIDENTIAL HEATING SYSTEMS BURNING WOOD RESIDUES

L. Morrison, Professional Loss Control Ltd.

The objective of this talk is to provide an overview of the insurance and certification aspects of residential heating appliances. Since insurance is based on risk (hazards), and equipment certification is an attempt to control specific hazards, an attempt has been made to review their status and effect on each other.

At present most insurance companies charge an owner a rate surchange for using wood heating equipment as the primary means for heating a residence. Companies are also requesting that questionnaires be filled out when wood heating systems are installed so they can get a clearer picture of the hazards associated with this equipment. It is important that these hazards be clearly defined if the insurance industry is to give credit to wood heating installations which meet a given standard of safety.

Heating appliance certification is a positive step toward controlling hazards through design, proper installation and safe operation of wood heating systems. An outline has been made of the Canadian standards for wood heating systems. The review is intended to indicate how specific hazards are controlled through these standards and certification. Persons interested in a more detailed discussion of the standards and certification process are referred to the referenced standards.

It is important that standards covering the design, installation, and operation of wood heating equipment by developed and used. In this way hazards will be controlled and a realistic picture of the risk associated with wood burning equipment unfold. Hopefully this will have a moderating effect on insurance rates and gain the confidence of the end user of this valuable energy source.

Additional notes:

1. HEATING EQUIPMENT LOSS EXPERIENCE

NFPA (U.S.)	20% dwg fires
CANADIAN	14% bldg fires

2. RESIDENTIAL INSURANCE RATE SURCHARGES (N.B.)

Insurance Company	Primary Heat Wood Furnace
A	$1.55 per $1,000 value
B	33%
C	35%
D	50%
E	100%

3. ULC SURVEY OF 1,000 CHIMNEY FIRES:

Fuel Involved	
Wood	848
Oil	25
Gas	4
Coal	2
Unknown	121

4. ULC SURVEY OF 1,000 CHIMNEY FIRES:

Cleaning Frequency	
Never	353
Annually	136
Twice a year	165
3 - 5 times	21
6 - 10 times	10
11 - 20 times	27
Over 20	2
Other	64
Unknown	222

5. WOOD BURNING APPLIANCES: Hazards

* Improper Installation
* Overfiring
* Burnback
* Jamming
* Careless Ash Handling
* Inadequate Maintenance

6. APPLIANCE INSTALLATION : Standards

* CSA B365 - M 1982
  Installation Code Solid - Fuel
  Burning Appliances
* NBC of Canada Part 9
* Suitability of Equipment
* Air for Combustion
* Controls & Safety Devices
* Mounting & Clearances

7. APPLIANCE CERTIFICATION

- CSA B 366.2 - M 1981

  Space Heaters for Use with Solid Fuels

- CSA B 366.1 - M 1981

  Solid Fuel-Fired Appliances for Residential Use

- CSA (in preparation)

  Independant Solid Fuel-Fired

  Appliances for Residential Use

8. APPLIANCE CERTIFICATION CRITERIA

- Operating Performance
- Unit Construction
- Safety Controls
- Fuel
- Instructions

5. BUILDING WOOD ENERGY SYSTEMS

5.1 WOOD ENERGY IN MAINE*,

N. Holmes, Maine State Office of Energy Resources

Several things have made wood energy use in Maine increase dramatically. These are public policy, the Public Utilities Regulatory Policies Act (PURPA), creative financing and S.D. Warren's cogeneration facility in Westbrook.

Wood energy consumption in Maine has doubled in all sectors (residential, commercial and industrial) from 1980 to 1982. In 1982, wood energy consumption in Maine was 2.6 million cords.

Maine is at the end of the energy pipeline. Energy expenditures from 1972-1982 tripled in the residential sector, quadrupled in the commercial sector, and quintupled in the industrial sector. (These figures are based on actual dollars and are not adjusted for inflation.)

Maine is ranked number 47 of the 50 states in per capita income. In the late 1970's, Maine was 80% dependent on foreign oil. In 1982, the figure was 61%.

What happened? Maine developed an energy policy that stressed conservation, the development and use of renewable resources in an environmentally sound manner, and energy self sufficiency to the greatest extent possible.

Since 90% of Maine or about 17.7 million acres is forested, it made sense to depend more heavily on the forest for energy. The ownership of the forested land is somewhat unique in that ten large pulp and paper companies and land management companies own half of the forested land, while the remaining half is owned by approximately 100,000 small landowners. Only 3% of the State is publicly owned.

---

* All figures used reflect short tons, green moisture basis, acres, U.S. currency and cords.

In addition to the Governor's energy policy stressing the development and use of renewable energy sources, several other factors are helping to spur wood energy development. The Department of Conservation (DOC), which contains the Maine Forest Service, got a new Commissioner about 2-1/2 years ago. This person had no preconceived notion about whether whole tree chipping was good or bad. After attending a whole tree chips for energy conference in 1982, he became very excited about the potential for whole tree chipping to improve the quality of Maine's poor quality forests.

Every ten years the U.S. Forest Service is required to survey the forest resource in every state. Maine's resurvey was begun in 1980, and completed in 1982. The resurvey showed that while the quantity of Maine's forests was increasing, the quality was decreasing. In 1970, 15% of all commercial trees five inches and above in diameter were cull. In 1980, the figure was 18%.

In 1983, a supply-demand analysis of the spruce-fir resource in Maine was completed. Approximately 8.8 million acres of Maine's forested land is in the spruce-fir type. Of this acreage, roughly 5.5 million acres has received severe budworm damage. The supply-demand analysis showed that shortly after the year 2000, Maine will experience about a 20 year shortfall of useable spruce-fir fiber.

The Commissioner of DOC is actively seeking companies to locate in budworm damaged areas and to use this material for space heat and/or cogeneration. This is one way to clear out the damaged trees and hopefully, protect the healthy trees and also prepare sites for replanting in budworm resistant species.

Another policy that is making wood energy visible is the feasibility of converting state facilities to wood and/or cogeneration. This effort has the support of the Governor, DOC, the Energy Office and the Bureau of Public Improvements.

In 1978, the U.S. Congress passed the Public Utilities Regulatory Policies Act (PURPA). This law mandates that utilities over a certain size buy power from small power producers and cogenerators (80 MW or less) at the utility's "avoided cost" of bringing the next increment of power on-line. It also required each state's Public Utiity Commission (PUC) to determine the "avoided cost" for each qualifying utility.

There have been two challenges to PURPA. The first was a state's rights challenge and the second challenged the "avoided cost" provision. PURPA was upheld in both cases by the U.S. Supreme Court. The court said that it was the Congressional intent to encourage the production of power from sources other than oil and nuclear and that the "avoided cost" was the correct cost for the utility to pay for power.

There are three qualifying utilities in Maine. The largest, Central Maine Power Company, covers 71% of the State's population and about 60% of the State's area. The Maine PUC began determining Central Maine Power Company's "avoided cost" in late 1981. The second week in January, 1984, the rate was finally set for the first 50 MW decrement. The levelized rate for a 15 year contract is 9.4 cents/kWh, for ten years it is 8.24 cent/kWh and for five years it is 5.67 cent/kWh.

Within ten days of when the rate was set, the first 50 MW decrement was almost gone. Within three weeks, the second 50 MW decrement was gone and within five weeks much of the third 50 MW decrement was gone. The PUC has begun emergency rule making to sort out the method of determining which company gets into what decrement. Of the first 150 MW, approximately 80 MW is proposed to be wood fired.

Although no rates have been set for the other two utilities, Interstate Foods in Ft. Fairfield has plans to build a 30 MW wood-fired cogeneratin facility and another company plans to build a total of 100 MW of wood fired electric generation in two or four plants. The power purchase contract is one important element of a wood fired cogeneration system; another is the financing.

Up until the 1981 Economic Recovery Tax Act, third party or creative financing was not prevalent. However, because of the combination of five year accelerated depreciation, the Energy Investment Tax Credit and the Investment Tax Credit, sometimes as much as 60% of the qualifying costs of a project can be written off. This has given firms access to capital at a reasonable cost and enabled energy projects that would normally have a low priority, because of capital rationing, to be funded. A firm needs to examine four criteria to determine whether or not third party financing is viable. First, "will it provide financial advantages?" Second, "Can the risks be managed to attract a third party financier at a reasonable cost?" Third, "Who benefits from the tax laws?" Fourth, "Can an operating arrangement that meets both the investor's and firm's needs be arranged?"

There are four basic approaches to third party financing; leasing; joint venture (partnerships); energy services contract; and shared savings. Of these four the energy services contract, shared savings or a combination of the two are the most common way wood conversions and cogeneration projects are being financed in Maine.

In a common scenario, the investor owns the energy efficiency improvements. The firm agrees to purchase steam from the investors and shares in any savings usually on a 20-80% or 40-60% basis. The savings are figured from a baseline figure that uses an average of the last three to five year's fuel cost.

One recent example in Maine is a wood fired cogeneration facility at Bates College. Investors approached the College with a proposal to build a new 1.4 MW wood fired cogeneration facility at no cost to the College but at 2.3 million dollars cost to the investors. In return the College would be required to purchase steam from the investors. The College's present heating system would stay in place and act as a backup system.

Bates agreed to the proposal. They will save 20% a year on their heating costs. After seven years, when the costs of the plant have been written off, Bates can buy the facility at fair market value.

S.W. Warren's wood fired cogeneration facility at Westbrook is the best example of what has made wood energy go in Maine. It showed people that the wood supply is available, that wood fired systems work and that third party financing is an appropriate way to finance a project.

Back in the mid 1970's, S.D. Warren, a division of Scott Paper Company and manufacturers of fine quality papers, needed to replace their boilers. A biomass boiler was one option they examined.

S.D. Warren is located in the largest metropolitan area in Maine. They own no woodlands themselves, although they do have a Tree Farm Family Program. In 1979, S.D. Warren began a study of yields from whole tree chipping different types of stands. They were unsure what to expect, but thought that 20 tons of biomass per acre was probably a good average. They were surprised to find that selectively cutting natural stands yielded an average of 40 tons per acre. Some clear cuts ranged as high as nearly 200 tons per acre.

S.D. Warren made the decision to install a new biomass boiler that would burn both coal and wood. Original plans called for 1,200 tons of wood and 600 tons of coal per day. However, the wood has been so successful that they now burn about 1,700 tons of wood per day and much less coal then originally planned. Annual usage is about 450,000 tons per year. The plant became fully operational in mid 1982 and their 1983 fuel usage will reflect this increase. By switching to wood for part of their fuel, S.D. Warren saves about a half a million barrels of oil a year. At current prices this represents approximately a 15 million dollar savings.

S.D. Warren generates 47 MW of electricity. About half of this is used internally, while the rest is sold to Central Maine Power Company under an existing contract. The plant owners have discovered that there are two profit centers at the plant, the paper operation and the cogeneration facility.

To ensure its wood supply, S.D. Warren contracts with over 20 whole tree chip operators. They also co-signed several bank loans for logging operators who wanted to chip for them. Chip operators are paid on a spout price plus transportation costs. Wood chips are coming from over 100 miles away in some instances.

Small woodlot owners have proved to be very receptive to whole tree chipping operations. They like the open parklike appearance of chipped stands. The good operators have year long waiting lists as word spreads about them from neighbor to neighbor.

Looking only at forest growth and sustained yield, a reasonable figure for biomass growth is 1.6 tons per acre per year. Subtracting out the 1981 harvest and assuming that one-third of the remaining growth is unavailable, about 10 million tons per year could go into energy projects. This equals roughly 22 projects the size of S.D. Warren.

Wood energy in Maine is increasing. Public policy, PURPA, creative financing and wood supply have come together in a very positive manner. The future of wood energy in Maine is quite promising.

5.2 A REGIONAL WOOD ENERGY INDUSTRY,

Greg McKenna, Neill & Gunter Ltd.

Good afternoon ladies and gentlemen. During the past day and a half we have heard several excellent discussions and have had a first hand look at several elements of the wood residue energy industry. During the next fifteen minutes or so we are going to be taking a broad look again at all of those elements of the industry, but from a business standpoint. We believe that this discussion will be of interest to equipment manufacturers, government representatives and businessmen in almost all parts of the wood industry, and, I hope, especially interesting to the entrepreneurs in the audience who are seeking promising new opportunities.

Our company, in association with Operation Improvement Ltd. of Edmundston was commissioned by the Energy Secretariat to carry out a study early in 1983. The purpose of the study really boiled down to answering the questions "Is wood energy supply a viable business? If so, what are the economic parameters which can make it successful?"

In our opinion it was very appropriate for the Energy Secretariat to have such a study conducted because the number of factors involved are complex. The opportunities are not immediately by obvious without a detailed examination of the potential markets, which are largely still undeveloped; the various possible sources of the raw material, the variety of wood fuel forms, and the variety of transportation and processing operations involved in their manufacturing and distribution.

What We will Cover

As I mentioned earlier, there are some real opportunities for entrepreneurs to potentially make some excellent profits by entering certain facets of the wood energy supply business. In fact, out of five potential or model businesses which we studied, three appear to be very attractive.

I would like now to walk through, so to speak, some of the key aspects of the study, the methods that were used, and the conclusions reached. In the course of this, Tables used will help to illustrate the points and information presented.

Markets

Any business must be, first and foremost, driven by filling a need, or in other words supplying a market. Within the study area the potential buyers of wood residue energy fuels can be grouped into three broad categories; namely, industrial and agricultural, commercial and institutional, and residential. Present use of energy in the form of electricity, petroleum products and wood were carefully examined and are shown summarized in Table I. Projections were then made of the potential for wood to replace the other energy forms. In the course of this market study, contacts were made with a large portion of the potential consumers in each of the first two sectors of the market, and the residential market was analyzed using information from N.B. Power, Statistics Canada, fuel oil distributors and others. As can be seen in Table 2, it was concluded that the maximum potential market in the three sectors is just over 220,000 bone dry metric tonnes per year. It was estimated that a new wood energy business or businesses could expect to capture a new market of about 11% of this, which together with the existing largely residential market, would reach 49,450 bone dry metric tonnes per year, about 22% of the maximum potential.

As a part of determining this available market, wood fuel sales prices were estimated, using a computer model which considered various factors including:

- oil prices,
- sales volumes for the various classes of customers,
- the money customers would have to spend to convert, operate and maintain the wood fuel storage, handling and combustion systems,
- the heat content and combustion efficiency of the various fuel forms,
- and the affect of existing conversion grants.

It was assumed that savings to the customer would have to provide a 20% return on his expenditures in order to induce him to convert. Sales price limits were established on this basis for each market sector and fuel form and are shown in Table 3.

Fuel forms considered in the study were wood chips, both green and dried, hogged sawmill residues, pelletized wood, and conventional fuel wood in the traditional 8 foot, 24 inch, 18 inch and 16 inch lengths both split and unsplit. The industrial/agricultural and commercial/institutional sectors would tend to be the large users of the chips and sawmill residue fuels, the pelletized wood could be attractive to all sectors, while the residential market would tend to use conventional fuel wood with more limited potential for the other fuel forms.

Raw Materials

The two major groupings of fuel types are:

1. Residues from existing wood processing mills including bark, sawdust, shavings, slabs and chips,
2. Biomass from the forest.

Forest biomass includes tops and branches of merchantable softwood and hardwood, non-commercial species such as partially rotten boles and unusable portions of burned logs, and trees removed from stands during pre-commercial and commercial thinning and conversion cut operations.

In other words the potential source of fuel is all biomass not presently used for commercial products such as sawlogs, pulpwood, pulp chips, poles and veneer logs.

All of the various sources for this material were examined in detail and costs were identified for producting the raw material from the various sources. The resulting projected costs at roadside for the various biomass fuels are then summarized in Table 4. As can be seen, the costs for the last three are reasonably close while residue from shortwood harvesting of pulpwood is considerably more expensive.

The total recoverable quantity of forest biomass was estimated to be 115,875 bone dry metric tonnes per year at these prices, which of course would be more than ample for the estimated market. In addition residues available from sawmill operations were estimated to be up to 19,654 bone dry metric tonnes per year, with a cost range for shavings, sawdust and bark of $1 - $6 per bone dry metric ton. The sawmill residues of course have competing buyers; any business planning to use that source for a portion of his raw material supply would be well advised to enter some long term agreements with the sawmill owners before proceeding.

Getting from Raw Material to the Markets

Obviously there are several operations and steps involved in bringing our raw material supply and our market demand together in a satisfactory way. (See Chart 1). Producing the raw material from forest biomass of course involves several gathering and harvesting operations, transport systems to deliver the material in most cases through a centralized plant operation which would be presumably located convenient to the raw material and the market, and finally customer delivery, storage and usage systems.

Five possible business models were identified in the study; namely:

1. A wood chip supply business,
2. A sawmill residue supply business,
3. A dried wood chip supply business,
4. A wood pellet supply business and
5. A fuel wood supply business.

Each of these was examined as an independent business. However in practice any viable models could be combined in various ways, and the results should be even more viable. By following the lines on Chart 1, one can see the various operations that were included under each model.

Each model was then examined in detail, again using a computer program which considered all of the normal factors involved in any business such as capital investment and working capital, sales volume, variable and fixed costs of the operations, interest on money borrowed, which was for purposes of the study was assumed to be that in excess of a 25% equity investment, depreciation and taxes. Five year pro forma projections were made for each model considering pessimistic, optimistic and probably case scenarios.

For purposes of the projections, it was assumed that, generally, the centralized operations would be owned by the business, and the various harvesting and transportation services would be contracted from existing outside operators and trucking firms.

Results

Chart 2 shows the key elements of the economic analysis for each of the five models. As that chart shows, the invested capital, sales volume, sales prices and total sales revenues are identified. From the sales revenues, variable and fixed costs, and interest are deducted to arrive at gross income. After depreciation and taxes, net profit is determined, and net profit was then compared to capital invested using the discount cash flow return on investment (DCFROI) method. It will be seen that models 1, 2 and 5 provide very attractive DCRFOI's and therefore appear to be very viable businesses.

Sensitivity of each model to significant changes in volume and in sales prices were examined. As might be suspected, sales prices of course have a very major impact on profitability. However in the case of the three viable models price reductions in the order of 17 to 50% below those estimated could occur before DCFROI would drop below 20%, which was assumed to be a minimum level attractive to the entrepreneur. Alternately, sales volume could drop to the levels shown on the chart before DCFROI dropped to the 20% level. Some of the key assumptions contained in the various models are identified toward the bottom of Chart 2.

For all of these business models, the business and labour skills, the technology, the equipment, are all generally available now within the area. Some specialized training would be required in a few areas such as furnace maintenance for solid fuel combustion, but any such training can be readily arranged through existing New Brunswick training institutions. The wood energy businesses identified could be established either as independent businesses or as additions to an existing wood related enterprise. However there would be some obvious potential benefits from adding it to an existing wood related enterprise. For example, there would be more reliable supplies of raw materials, as well as savings in overhead costs through the sharing and increased utilization of existing manpower and equipment, and of harvesting and transportation equipment, if integrated with another wood related business.

I hope that this discussion has whetted the appetites of some of you to look into the business opportunities in more detail than one can cover in a fifteen minute presentation such as this. For those of you who are interested, copies of the study report are available from the Energy Secretariat. Thank you for your attention.

T A B L E 1

CONSUMPTION BY ENERGY SOURCE
PER CENT OF TOTAL

Sector	Wood	Wood Residue	Petroleum Products	Electri-city	Total
Industrial & Agricultural	0.	8.2	23.3	7.7	39.2
Commercial & Insitutional	0.	0.	11.9	3.9	15.8
Residential	8.1	0.	24.9	12.0	45.0
All Sectors	8.1	8.2	60.1	23.6	100.0

T A B L E 2

ESTIMATED WOOD ENERGY MARKET
BONE DRY TONNES/YEAR

Sector	Maximum Potential Market	New Market Share	New Market	Existing Market	Total Market
Industrial & Agricultural	90,300	15%	13,545	1,300	14,845
Commercial & Insitutional	46,100	5%	2,305	300	2,605
Residential	84,000	10%	8,400	23,600	32,000
Total	220,400	11.0	24,250	25,200	49,450

T A B L E 3

WOOD FUEL SALES PRICE LIMITS
$/BONE DRY TONNE

	Chips Green 50% M.C.	Chips Dried 20% M.C.	Pellets 10% M.C.	Fuel Wood 30% M.C.
Probable Case	55.00	63.00	82.00	74.00

T A B L E 4

FOREST BIOMASS PRODUCTION COSTS

	Range $/Bone Dry Tonne
Harvesting Residues	
- Shortwood	62 - 90
- Full-Tree to Roadside	33 - 35
Full-Tree Chips	28 - 30
Fuelwood (8')	34 - 36

IS WOOD ENERGY SUPPLY A VIABLE BUSINESS ?
THIS STUDY SHOWS THAT IT CAN BE....

THIS FEASIBILITY STUDY FOR A MODEL WOOD ENERGY INDUSTRY WAS CARRIED OUT DURING 1983 BY NEILL AND GUNTER LIMITED AND OPIM LTD. FOR THE ENERGY SECRETARIAT, GOVERNMENT OF NEW BRUNSWICK. IT WAS PREPARED UNDER THE CANADA-NEW BRUNSWICK CONSERVATION AND RENEWABLE ENERGY AGREEMENT.

CHART NO. 1

RAW MATERIAL SUPPLY — PROCESSING — MARKETS

RAW MATERIAL GATHERING HARVESTING SYSTEMS

TRANSPORT SYSTEMS

CENTRALIZED OPERATIONS

CUSTOMER DELIVERY/STORAGE USE SYSTEMS

ROADSIDE CHIPPING SET-UP

STANDING WOOD

CUT / SKID

BRANCHES, TOPS FROM PULPWOOD HARVESTING

FELLER / BUNCHER

ON-SITE CHIPPING SET-UP

SAWMILL RESIDUE (BARK, SAWDUST)

LOADER

SELF-UNLOAD VANS

SHORTWOOD TRUCKS

DUMP TRUCKS

SCALE

UNLOAD

STORAGE PILE CHIPS

LOAD

MECH. DRYING

PELLET-IZING

UNLOAD

STORAGE PILE ROUNDWOOD

LOAD

SLASHER

SPLITTER

STORAGE PILES SAWMILL RESIDUE

LOAD

DISC SCREEN & HOG

UNCOVERED STORAGE

COVERED STORAGE

SCALE

SELF-UNLOAD VANS

FUEL WOOD TRUCK

INDUSTRIAL AGRICULTURAL

COMMERCIAL INSTITUTIONAL

RESIDENTIAL

WOOD ENERGY BUSINESS MODELS

MODEL NO. 1 - WOOD CHIP SUPPLY BUSINESS

MODEL NO. 2 - SAWMILL RESIDUE SUPPLY BUSINESS

MODEL NO. 3 - DRIED WOOD CHIP SUPPLY BUSINESS

MODEL NO. 4 - WOOD PELLET SUPPLY BUSINESS

MODEL NO. 5 - FUEL WOOD SUPPLY BUSINESS

COMPARISON OF ECONOMIC RESULTS - 5 MODELS

BASED ON "MOST PROBABLE" RESULTS SCENARIOS. SECOND YEAR OF OPERATION

CHART NO. 2

MODEL NO.	1	2	3	4	5
BASIC DESCRIPTION	WOOD CHIP SUPPLY	SAWMILL RESIDUE SUPPLY	DRIED WOOD CHIP SUPPLY	WOOD PELLET SUPPLY	FUEL WOOD SUPPLY
CAPITAL INVESTED	$ 416.000	$ 647.400	$ 1.575.000	$ 2.476.000	$ 265.000
SALES VOLUME, BDT/Y	16.960	16.960	16.960	16.960	8.980
SALES PRICE, $/BDT	58.85	58.85	69.55	87.74	79.18
TOTAL SALES REVENUES	998.067	998.067	1.179.533	1.488.027	711.670
VARIABLE COSTS (RAW MATERIAL, TRANSPORT, OPERATIONS)	671.520	219.388	740.827	484.221	466.679
FIXED COSTS (INSUR, POWER, ADMIN, MAINT, MISC)	70.188	104.607	188.919	321.110	88.581
INTEREST	24.211	12.397	139.952	158.063	18.086
GROSS INCOME	232.148	661.674	109.835	524.633	138.324
DEPRECIATION & TAXES	94.020	319.349	235.840	420.062	53.262
NET PROFIT < LOSS >	138.129	342.325	<126.005>	104.571	85.062
5 YR RETURN ON INVESTMENT *	65.4%	71.2%	8.9%	17.3%	77.7%
SALES VOLUME TO YIELD 20% MIN DCFROI (BDT/YR)	7.350	5.730	22.100	17.060	4.340
SOME KEY ASSUMPTIONS	TABLE	TABLE	OF [illegible]	[illegible]	TABLE
RAW MATERIALS	STANDING TREES BRANCHES & TOPS FROM PULPWOOD HARVESTING	SAWMILL RESIDUES (BARK & SAWDUST)	AS IN 1	AS IN 1	STANDING TREES
PLANT & EQUIPMENT	OFFICE, MOBILE EQUIPT (2) TRUCK SCALE	AS IN 1 + PLANT B'LDG + HOG & SCREEN SYSTEM	AS IN 2 + MECH DRYING SYSTEM	AS IN 3 + PELLETIZING SYSTEM	OFFICE, MOBILE EQUIPT. (2) LOG SLASH & SPLIT SYSTEM
WORK FORCE	2	2	3	4	3
CONTRACT OUT	HARVESTING, FIN. PROD TRANSPORTATION	AS IN 1	AS IN 1	AS IN 1	AS IN 1
CUSTOMERS	ALL 3 SECTORS SMALL RES. MARKET	AS IN 1	AS IN 1	ALL 3 SECTORS	RESIDENTIAL
FINISHED PRODUCT DELIVERED	SELF-UNLOAD VANS	SELF-UNLOAD VANS	SELF-UNLOAD VANS	SELF-UNLOAD VANS	VARIOUS TRUCKS
EQUIVALENT NO. 2 OIL $/BDT	124 $/BDT	124 $/BDT	147 $/BDT	151 $/BDT	124 $/BDT

* CALCULATED USING DISCOUNT CASH FLOW RETURN ON INVESTMENT METHOD (DCFROI)

6. The Organizing Committee

E.T. Owens, Director of N.B. Wood Energy Program, Research and Productivity Council, Fredericton, N.B. E3B 5H1

Maurice Robichaud, Symposium Chairman, N.B. Energy Secretariat, Fredericton N.B. E3B 5H1

Jeff Solway, Symposium Co-ordinator, N.B. Energy Secretariat, Fredericton N.B. E3B 5H1

7. Symposium Staff (N.B. Energy Secretariat)

John Christenson	Matthew MacKay
Sydelie Grobe	Marie-Lynn Savoie
Terry Ludford	Lynne Cyr-Vitone

8. Speakers

Mr. Jan Ellingsen
Boise Cascade Canada Ltd.
Box 1020
Newcastle, N.B. E1V 3M8

Mr. R.G. McCullough
Department of Commerce & Development
P.O. Box 6000
Fredericton, N.B. E3B 5H1

Mr. E.S. Fellows
E.S. Fellows and Associates
404 Queen St.,
P.O. Box 354
Fredericton, N.B. E3B 1B6

Mr. P. McKenna
Neill & Gunter Ltd.
PO Box 713
Fredericton, N.B. E3B 5B4

Mr. Doug Gorman
ADI Ltd.,
Box 44, Station A
1115 Regent St.,
Fredericton, N.B. E3B 4Y2

Mr. Paul McKinley
Fraser Inc.
27 Rice Street
Edmundston, N.B. E3V 1S9

Ms. Nancy Holmes
Energy Resource Planner
Office of Energy & Resources
State House Station 53
Augusta, Maine 04333

Mr. L. Morrison
Professional Loss Control Services
197 Charlotte Street
Fredericton, N.B. E3B 1L3

Mr. J. Hornby
J.D. Hornby Ltd.
RR#1
Hunter River, P.E.I. C0A 1N0

Prof. Jeremy Rickards
Faculty of Forestry
University of New Brunswick
Box 4400
Fredericton, N.B. E3B 5A3

M. Jean L. LaPlante
Dept. Of Natural Resources
PO Box 398
Edmunston, N.B. E3V 3L1

Dr. Marc Schneider
Faculty of Forestry
University of New Brunswick
Box 4400
Fredericton, N.B. E3B 5A3

Prof C.A. Short
Faculty of Forestry
University of New Brunswick
Box 4400
Fredericton, N.B. E3B 5A3

Dr. C.R. Silversides
R.R. #1
Prescott, Ont. K0E 1T0

Dr. Norman Smith
Dept. of Agricultural Engineering
University of Maine
Orono, Me. 04469

Mr. W. Torunski
Irving J.D. Limited
284 Union Street,
Saint John, N.B. E2L 1B7

Dr. Gerritt Van Raalte
Canadian Forest Service
Maritime Forest Research Cent.
P.O. Box 4000
Fredericton, N.B. E3B 5A3

9. Delegates

Dr. Donovan Abbott
Research and Productivity Council
Box 6000
Fredericton, N.B. E3B 5H1

Mr. D.C. Campbell
Tractor & Equipment
874 York Street
Fredericton, N.B. E3B 3R8

Mr. David Arsenault
Energy Branch
Dept. of Economic Development
P.O. Box 2703
Whitehorse, Yukon Y1A 2C6

Mr. Dick Canavan
Research and Productivity Council
PO Box 6000,
Fredericton, N.B. E3B 5H1

1E 698
Mr. Lionel Arsenault
PO Box 5001
Grand Falls, N.B. E0J 1M0

1E 732
Mr. Eldon Carson
Canadian Morbark Ltd.

PrinceWilliam, N.B.

Mr. Jean-P. Arsenault
P.E.I. Dept of Energy & Forestry
PO Box 2000
Charlottetown, P.E.I. C0B 2E0

Mr. Claude Chiasson
Maritime Forest Ranger School
PO Box 1
Bathurst, N.B. E2A 3Z2

Mr. Bill Buggie
Nfld. Dept. Forest Resource & Lands
Bldg. 810
Pleasantville, NFLD. A1A 1P9

Mr. Harvey Clavette
Edmunston Hospital
54 - 21 Avenue
Edmunston, N.B. E3V 2C1

Mr. Peter Burchell
N.S. Dept. Mines & Energy
1690 Hollis Street
Joseph Howe Bldg.
Halifax, N.S. B3J 1V8

Mr. Wayne Clowater
Dept. of Natural Resources
PO Box 6000
212 Queen Street
Fredericton, N.B. E3B 5H1

M. Laurie Collette
N.S. Dept. of Agriculture
PO Box 6000
Fredericton, N.B. E3B 5H1

Mr. C.J.P Collin
Operation Improvement Ltd.,
147 Victoria St.
PO Box 362
Edmundston, N.B. E3V 3L1

Mr. Eric Comeau
Lands & Forest
1791 Barrington Street
Toronto Dominion Bldg.
Halifax, N.S. B3J 3K9

Mr. Don Corey
Fraser Inc.
27 Rice Street,
Edmundston, N.B. E3V 1S9

Mr. John Corey
McCain Foods

Florenceville, N.B. E0J 1K0

Mr. Bill Denny
Dept. of Natural Resources
PO Box 6000
Fredericton, N.B. E3B 5H1

Mr. John Devlin
Neill & Gunter
PO Box 713
Fredericton, N.B. E3B 5B4

Mr. Robert Dick
Woodlot Service Ltd.,
320 Maple St.,
Fredericton, N.B. E3A 3R4

Mr. Larry Douglas
Dept. of Commerce and Development
PO Box 6000
Fredericton, N.B. E3B 5H1

Mr. Hugh Drummond
Research and Productiviy Council
PO Box 6000,
Fredericton, N.B. E3B 5H1

Mr. Martin Eisenhauer
Dale Forestry Ltd.
PO Box 1331
Lunenburg, N.S. B0J 2C0

Mr. Edward Flanagan
Hotel Dieu Hospital
53 Lobban Ave.
Chatham, N.B. E1N 2W9

Mr. Ian Flann
Energy, Mines and Resources
460 O'Connor Street
Ottawa, Ont. K1A 0E4

Mr. Gary Fraser
Dept. of Commerce and Development
Box 6000
Fredericton, N.B. E3B 5H1

Mr. John Fudge
Dept. of Education
P.O. Box 6000
Fredericton, N.B. E3B 5J1

Mr. Jean F. Gingras
Energy , Mines and Resources
580 Booth Street
Ottawa, Ont. K1A 0E4

Mr. Michel Godbout
Consolidated Bathurst Inc.
891 Main Street
Bathurst, N.B. E2A 4A3

Mr. Herbert Goodine
Tilley Manufacturing Ltd.
R.R.#2
Arthurette, N.B. E0J 1C0

Mr. Joakim Hermelin
Department of Natural Resources
PO Box 6000,
Fredericton, N.B. E3B 5H1

Mr. A.J. Hiscock
Island Energy Corporation
Shaw Building
P.O. Box 2000
Charlottetown, P.E.I. C1A 7N8

Mr Norman Hudson
Public Service Dept.
State Office Bldg.
Montpellier, VT. 05602

Mr. David Irwin
School Bldg. Division
PO Box 6000
Fredericton, N.B. E3B 5H1

Mr. John Kipping
Dept. of Forestry,
University of New Brunswick
Fredericton, N.B.

Dr. J. Kyle
Director, Forestry School
Lakehead University
Thunder Bay, Ont. P7B 5E1

Mr. David Lamont
State Energy Office
State Office Building
4 East State Street
Montpellier, Vt. 05602

Mr. Paul Landry
Energy, Mines & Resources
835 Champlain Street
Dieppe, N.B. E1A 1P6

Mr. Leopold LeBlond
Energy Tube Ltee.
C.P. 366
Edmunston, N.B. E3V 3L1

Mrs. McInnis Leek
Washburn & Gillis Ass.
Suite 527
1657 Barrington Street
Halifax, N.S. B3J 2A1

Mr. David Libby
Enersave Systems Ltd.,
P.O. Box 187
Restigouche Rd.
Oromocto, N.B. E2V 2G5

Mr. Duncan MacAdams
N.S. Forest Product Ass.
30 Mill Street
PO Box 696
Truro, N.S. B2N 5E5

Mr. D.S. MacKay
D.S. MacKay and Associates Ltd.,
Box 340
Hampton, N.B. E0G 1Z0

Mr. Gilbert MacNutt
Dept. of Health
PO Box 6000
Fredericton, N.B. E3B 5H1

Mr. Paul McAllister
R.R. #1

Millerton, N.B. E0C 1R0

Mr. Bruce McCallum
Energy Mines & Resources
98 Water Street
Summerside, P.E.I. C1N 4M1

Mr. Paul McKnight
P.E.I. Forest Service
PO Box 2000
Charlottetown, P.E.I. C1A 7N8

Mr. B.B. Meadows
Department of Natural Resources
P.O. Box 6000
Fredericton, N.B. E3B 5H1

Mr. L. Morrison
197 Charlotte Street
Fredericton, N.B. E3B 1L3

Mr. Barry Nelson
Dept. of Natural Resources
208 Queen Street
PO Box 6000
Fredericton, N.B. E3B 5H1

Mr. Gerald O'Brien
Dept. of Commerce and Development
PO Box 6000,
Fredericton, N.B. E3B 5H1

Mr. Craig Parkine
Mechanical Equipment Co.

Burlington, Vt.

Mr. Michael Pottie
Forest Eng. Research Inst. of Can.
143 Place Frontenac
Pointe-Claire, Quebec H9R 4X7

Mr. Reg Reid
McCain Foods

Florenceville, N.B. E0J 1K0

Mr. Tony Rombold
Maritime Lumber Bureau
PO Box 459
Amherst, N.S.

Mr. Peter Rundle
Woodcan Ltd.
128 Alexander St.,
Fredericton, N.B. E3B 1Y6

Mr. Stan Rust
Tractors & Equipment Ltd.
PO Box 1326
Fredericton, N.B. E3B 5E4

Mr. Jean-C. Savoie
PO Box 370
Saint Quentin, N.B. E0K 1J0

Mr. Ron Sisk
Community Improvement Corp.
329 St. John Street
Fredericton, N.B. E3B 5H1

Mr. Burtt Smith
Dept. Natural Resorces
PO Box 6000
212 Queen Street
Fredericton, N.B. E3B 5H1

Dr. John Synnott
Research and Productivity Council
Box 6000
Fredericton, N.B. E3B 5H1

Mr. John Tera
P.E.I. Energy Corp.
PO Box 2000
Charlottetown, P.E.I. C1A 7N8

Mr. George Walsh
Maritime Forest Ranger School

R.R. # 3
Fredericton, N.B. E3B 4X6

Mr. Alex Windsor
Dept. Of Mines & Energy
PO Box 4750
St. John's, NFLD. A1C 5T7